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ENVIRONMENTAL IMPACT STATEMENT
FOR THE AIR POLLUTION VARIANCE

REQUESTED BY:

THE ANACONDA COMPANY
FOR ITS SMELTER AT ANACONDA, MONTANA

February 7, 1974

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FOREWORD

This statement has been prepared by the Environmental Sciences Division of the State Department of Health and Environmental Sciences, pursuant to the Montana Environmental Policy Act, (MEPA) Section 69-6504(b)(3).

The MEPA requires preparation of an environmental impact statement whenever a state agency is considering some action that could result in a significant impact on the environment. The action contemplated in this case is a decision regarding an application for an air pollution variance by The Anaconda Company for their copper smelter in Anaconda, Montana.

This department, with the help of other agencies and members of the public, must decide whether granting the variance would result in the continuation of emissions into the air to an extent sufficient to constitute danger to the public health or safety, and whether denial of the variance would produce hardship without equal or greater benefits to the public.

Because of the need to hold hearings as soon as possible, there will be no 15-day extension of the 30-day waiting period following issuance of this statement. All comments should be sent to Daniel Vichorek, Technical Writer, Environmental Sciences Division, Cogswell Building, Helena, Montana, 59601, no later than 30 days from the issue date.

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SUMMARY

The Anaconda Company has requested a variance from the state's sulfur oxide emission standard. The variance would be granted for one year, which is the maximum period for which a variance may be granted, although they may be renewed if such action seems reasonable.

The company said it could not now operate the plant to comply with the standard and it needs time to continue the design and construction of additional unspecified air pollution control devices.

It has been demonstrated to the satisfaction of this department that equipment is available at a reasonable cost to bring the smelter into compliance with the emission standard. Such equipment is in operation on other copper smelters similar to the Anaconda operation.

Lacking adequate emission control, the smelter causes frequent gross violations of the sulfur oxide ambient standards in the Deer Lodge Valley, resulting in damage to vegetation and threats to the health and property of the residents.

Considering all the facts above, this department concludes that the benefits that might result from granting the variance would be more than negated by the resulting impacts on the environment and the public.

The department therefore recommends that the State Board of Health and Environmental Sciences deny the variance.

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I. INTRODUCTION

A. Description of the Proposed Action

1. The Anaconda Company has requested a variance from Section 16-2.14(1)-S1470 of the Montana Administrative Code, pertaining to sulfur oxide emissions from the copper smelter at Anaconda (Appendix A).

The pertinent portion of this code says "No person or persons shall cause, suffer, allow or permit to be discharged into the outdoor atmosphere from any copper, zinc or lead smelting operation or any slag treatment plant reduced sulfur in excess of the amount shown in the following table."

Total Feed of Sulfur lb/hr	Allowable Sulfur Emission, lb/hr Cu	Zn	Pb
1,000	100	100	100
5,000	500	394	348
10,000	1,000	704	593
20,000	2,000	1,270	1,000
40,000	4,000	2,310	1,000
60,000	6,000	3,210	1,000
80,000	8,000	4,120	1,000
100,000	10,000	5,000	1,000
Over 100,000	10,000	5,000	1,000

2. Definition and Purpose of Variances

Under the Montana Clean Air Act, Section 69-3917, any person who owns or controls any plant, building, structure, process or equipment may apply to the State Board of Health for an exemption or partial exemption from rules or regulations governing the quality, nature, duration or extent of air polluting emissions.

The Board may grant such exemptions only if it finds that the emissions occurring or proposed to occur do not constitute a danger to public health and do not constitute a danger to public safety and only if compliance with the rules or regulations from which variance is sought would produce greater public hardship than public benefits.

The act states further that no exemption or partial exemption shall be granted. . . except after public hearing on due notice and until the Board has considered the relative interests of the applicant, other owners of property likely to be affected by the emissions, and the general public.

Variances may not be granted for periods greater than one year at a time, but they may be renewed under certain conditions stipulated by the Board.

B. Company's Proposals Per Variance

The Anaconda Company presently is producing about 34 million pounds per month of anode copper. The only equipment in operation as of February, 1974, for control of sulfur oxide emissions is the 660 tons per day (T./day) sulfuric acid plant which will retain about 38% of the total sulfur input to the smelter when rated capacity is achieved. When the Arbiter plant becomes operational in late 1974, approximately 50% of the input sulfur to both the pyrometallurgical and hydrometallurgical smelters will be retained.

In its request for a variance from Regulation 16-2.14(1)-S1470(2), submitted to the Montana State Department of Health and Environmental Sciences, The Anaconda Company has asked that:

1. A variance be granted for one year.
2. Operation of the applicant's smelter at Anaconda, Montana, be allowed to continue because it does not include equipment to restrict sulfur emissions to 10% of total feed as required by the regulation.
3. Additional time be granted to continue design and construction of additional air quality control devices.

The future control plan as envisioned by The Anaconda Company is outlined below:

1. Complete Phase I of the smelter expansion program as established in 1971. This phase includes the 660 T./day sulfuric acid plant, the installation of a new flue and water-cooled hood system to exhaust converter off-gases.

2. Construction of the Arbiter hydrometallurgical plant to produce an additional 6 million pounds of copper per month. Since this plant will not discharge sulfur oxide gases, the control of the input sulfur to the entire complex will be increased to about 50%.

3. Installation of a fluo-solids roaster and electric furnace to replace the drying and reverberatory furnaces.

Completion of Phase I of the smelter expansion program will partially achieve compliance with state regulations for sulfur oxide emissions. The company usually refers to the sulfuric acid plant as an environmental control, but about 250 T./day of the acid produced is used for concentrate and precipitate production at the Butte mines. A contract to sell 50,000 tons of sulfuric acid in 1974 has been obtained. This amount of acid is equivalent to a daily production of 137 tons for 365 days. The two uses of the acid amount to almost 59% of rated capacity (Reference 1).

The Anaconda Company has not stated in the variance request that means for sulfur oxide removal from the flue gases from the proposed fluo-solids roaster or electric furnace would be installed. As of February, 1974, no construction applications have been requested nor any construction schedules released for these two units. Nor does the Company state in the variance request that additional converter off-gases will be treated.

II. DESCRIPTION OF PLANT AND PROCESSES

A. Basic Manufacturing Processes

1. Pyrometallurgical Smelter

The Anaconda Company smelter at Anaconda, Montana, treats ores, copper concentrates and precipitates to produce anode copper. About 2100 T./day of raw materials, based on company production records from January through August, 1973 (Ref. 2), are used in the smelting process with about 1.17 million pounds per day (lb/day) of anode copper produced. A schematic flow diagram of the smelter is shown in Figure 1. Concentrates now come by rail from the Weed Concentrator at Butte, from Yerington, Nevada and the Brittania and Craigmont mines in British Columbia, Canada. Starting about November, 1973, copper ore was shipped by rail from the Continental East Pit at Butte. A future source may be the Twin Buttes property in Arizona but this is not likely to happen for several years. Precipitates are shipped by rail from the Precipitate Plant located near the Berkeley Pit in Butte, from Yerington, Nevada, and from British Columbia (1).

The approximate proportions of plant feed from each source are shown in Table 1. The overall copper and sulfur contents of the smelter feed (concentrates and precipitates) are about 35.1% and 31.4% respectively. An approximate smelter sulfur balance is shown in Figure 2.

Ore from the Continental East Pit is crushed at the East Anaconda crusher and concentrated in the facilities at the smelter complex. All concentrates and limestone are dried in the eighteen multiple tray roasters in roaster building no. 2. Even though these facilities were originally used as roasters, only drying is now done. Roaster building no. 1 is only used for storage.

The smelting process begins in the reverberatory furnaces. Three natural gas fired furnaces, each about 120 feet long, 60 feed wide and 50 feet high, consuming about 6.2 billion cubic feet of natural gas each year (1) are periodically charged with limestone-concentrate mixture, silica rock, and converter slag.

Figure 1. Flow Diagram - Anaconda Smelter

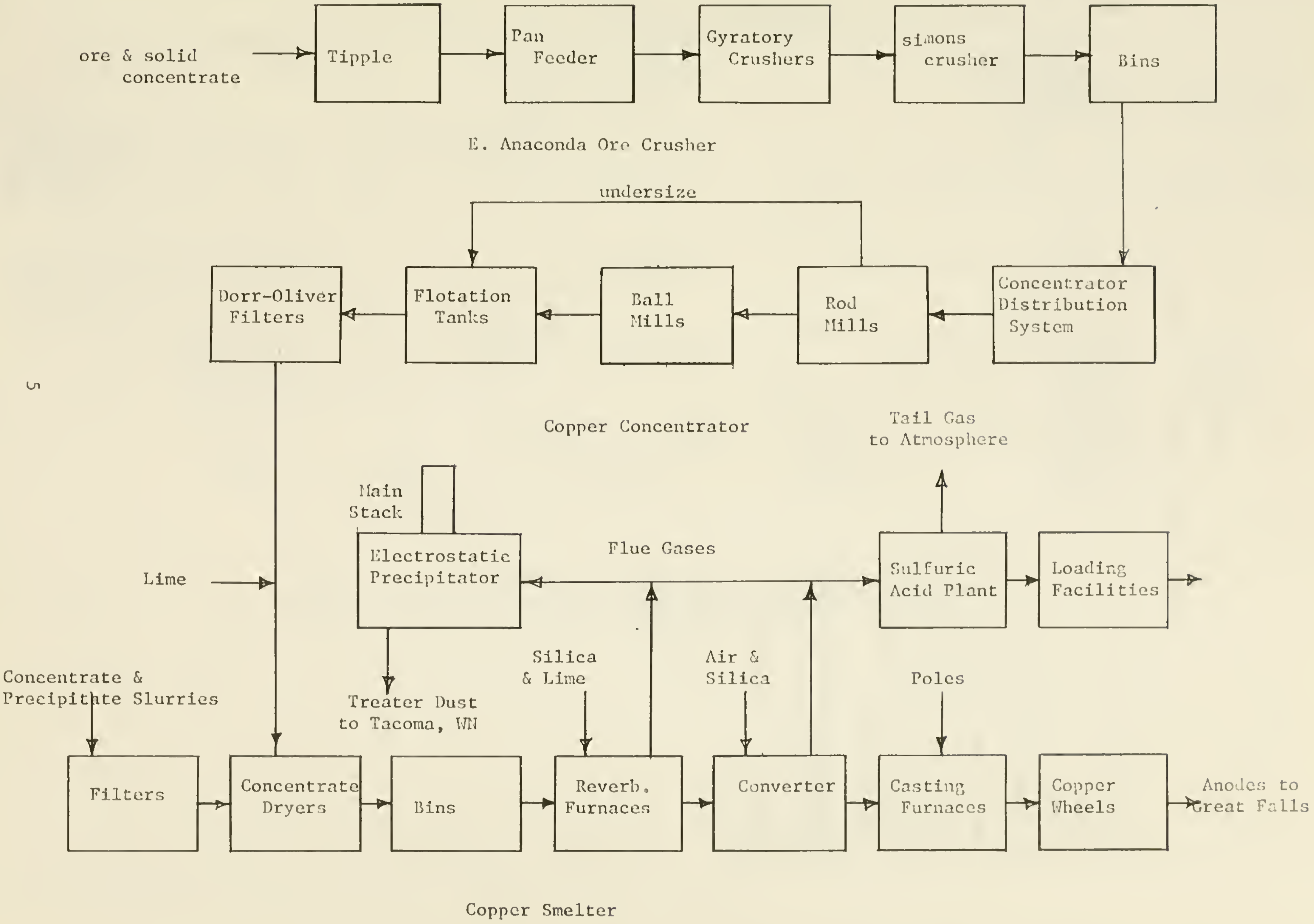


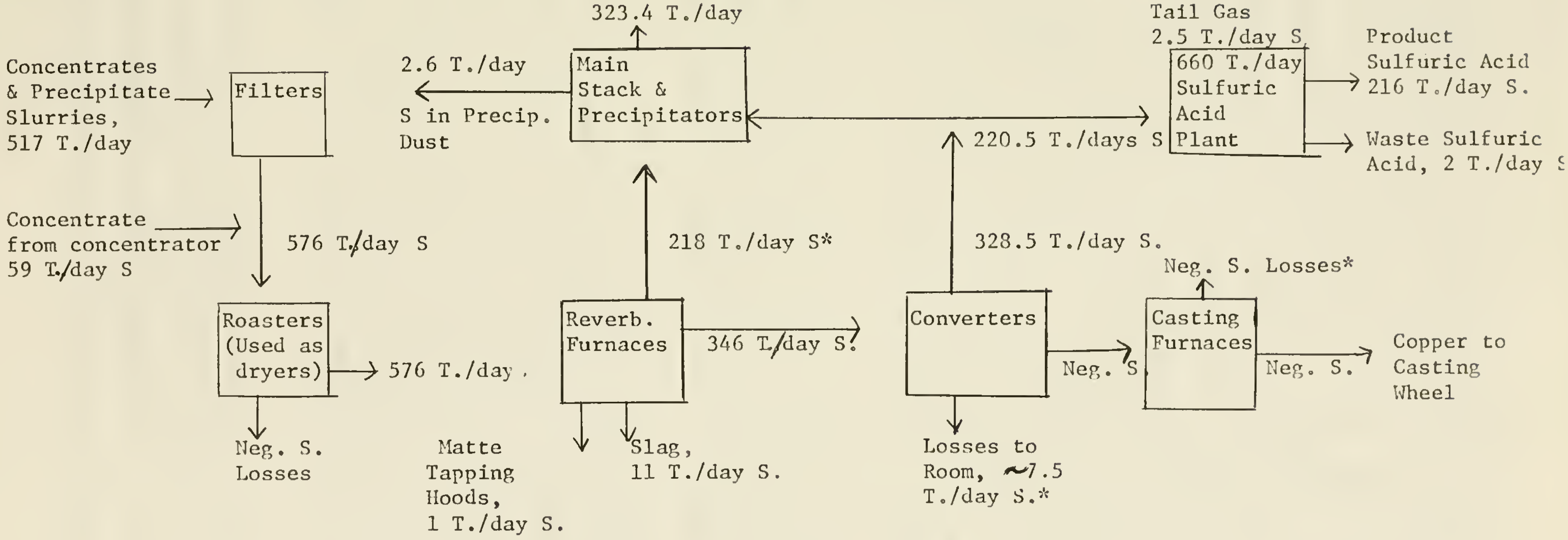
TABLE 1

Smelter Copper Feed as of October 24, 1973

Source	% of Total Ores Concentrates & Precipitates	% Sulfur in Column 1	Product of Columns 1 & 2
Weed Concentrator, Butte	70.2	36.3	2548
Concentrates, Yerington, Nevada	13.1	31.5	413
Precipitates, Yerington, Nevada	3.5	1.3	005
Concentrates, Brittania Mine B.C., Canada	5.0	35.3	177
Precipitates, Brittania Mine, B.C., Canada	0.2	2.0	0.46
Precipitate Plant, Butte	8.0	nil	0.00
Total	100.0	-	3143.46
Average	-	31.4	

FIGURE 2

Approximate Smelter Sulfur Balance with Fully Operational Sulfuric Acid Plant


Concentrates & Precipitate Slurries, 517 T./day
Filters
Concentrate from concentrator 59 T./day S
576 T./day S
Roasters (Used as dryers)
Neg. S. Losses
576 T./day
2.6 T./day
S in Precip. Dust
323.4 T./day
Main Stack & Precipitators
218 T./day S*
Reverb. Furnaces
Matte Tapping Hoods, 1 T./day S.
Slag, 11 T./day S.
346 T./day S.
220.5 T./days S
328.5 T./day S.
Converters
Losses to Room, ~7.5 T./day S.*
Neg. S
Tail Gas 2.5 T./day S
660 T./day Sulfuric Acid Plant
Product Sulfuric Acid 216 T./day S.
Waste Sulfuric Acid, 2 T./day
Neg. S. Losses*
Casting Furnaces
Neg. S.
Copper to Casting Wheel

*Estimated quantities, Never measured by The Anaconda Company
Note: The sulfur in natural gas is negligible

Limestone and silica are fluxing agents. The furnaces are kept nearly full at all times and the contents are maintained at about 2000°F. The emissions from the reverberatory furnaces consist of particulate matter in the form of metallic fumes, sulfur oxides, nitrogen oxides, and carbon monoxide. Currently the flue gases containing these emissions are cooled in spray chambers from about 2400°F. to 700°F. and then flow through the main flue to the electrostatic precipitators at the base of the main stack. The slag removed from the reverberatory furnaces is moved by a water filled flume to a pond and then by drag-line to the dump. The slag contains about 2% sulfur. The product, copper matte, is transferred by ladles to the converters (furnaces). The matte consists of about 46% copper, 24% iron, 25% sulfur and 5% other materials.(2,29) About 60% of the sulfur in the feed remains in the matte, about 38% is contained in the furnace off-gases. This reverberatory furnace off-gas contains about 1 - 2% sulfur dioxide (3).

The copper matte is converted to blister copper in one of the eight converters. Air, silica, copper matte, and casting furnace slag comprise the charge to these furnaces. The primary purpose of these furnaces is to reduce the metallic sulfides of the matte into metallic copper, leaving slag and releasing sulfur oxide gases. The sulfur oxides that are driven off, about 98% of the sulfur in the converter charge, are collected in a water-cooled hood and flue system which is designed to have a collection efficiency of 95% (3). No measurements of actual efficiency have been made. About 67% of this flue gas goes to the 660 T./day sulfuric acid plant for conversion to sulfuric acid. The other 33% passes through the main flue and main stack to the atmosphere. The above efficiencies refer to both collection and treatment; they should be kept separately in mind.

The sulfuric acid plant includes an 80,000 standard cubic feet per minute (SCFM) Ducon wet scrubber which cleans the inlet gas. About 2% of the sulfur oxides entering this unit are dissolved by the water. Of the remaining 98% about 99% is converted to sulfuric acid and the remainder, about 500 parts per million (ppm) or 5.0 T./day sulfur dioxide, is discharged to the atmosphere through a 120 foot stack. In summary, the acid plant removes about 67% of the sulfur in the converter off-gases and only about 38% of the total smelter input sulfur (4).

The slag formed in the converters is relatively high in copper and is returned to the reverberatory furnaces for additional processing. The converter product, blister copper, is transferred by ladle to one of four casting furnaces where it is treated by "poling", an oxide reducing process, and poured into the casting wheels to form copper anodes (3). Low concentration emissions from two of these furnaces are collected and exhausted outside the building as an occupational health control measure. The copper anodes are shipped to Great Falls, Montana, for purification.

A silica rock quarry about 3 miles Southwest of the smelter complex supplies 120-320 T./day of material for the smelting process (5). Transportation is by rail.

A limestone quarry several miles west of the town of Anaconda produces about 1250 T./day of rock (calcium carbonate) most of which is processed in two lime kilns for use in the concentration processes at Butte and Anaconda and for waste water neutralization (6). No processing of the limestone is required when it is used as flux in the smelting process.

Lime kiln no. 1 receives about 300 T./day of limestone rock and lime kiln no. 2 receives about 800 tons (6). This limestone rock is "burned" in natural gas fired rotary kilns at about 2000°F. to form "burnt lime" (calcium oxide). This material is then slaked with water to form milk of lime (calcium hydroxide) and then transported by rail to the Weed Concentrator or other usage points. About 165 x 10^6 cubic feet (ft.^{3}) of natural gas are consumed per month by the two lime kilns (1).

The ore/crusher at East Anaconda now processes Butte ore two shifts per day. About 14,000 T./day of ore are crushed and sent to the copper concentrator where the amount of material is reduced to 175 T./day containing 31.5% copper and 33.6% sulfur (7). The concentrator operates on a continuous basis.

As of February, 1974, twelve natural gas fired boilers were operating at the smelter producing steam primarily for heating buildings. The total rating of these boilers is 2,450 horsepower. This is equivalent to a steam generating capacity of about 100,000 lbs/hr. Natural gas consumption by these boilers is 108,000 cubic feet per hour (7). Generation of steam from the hot reverberatory furnace flue gases was discontinued in 1972 (8). When in use, the last waste heat boiler generated about 20,000 lbs/hr of steam.

Many processing areas in the smelter complex are now inactive. This includes three sulfuric acid plants with acid capacities of 200, 150 and 100 T./day, the arsenic plant, the zinc crusher, zinc concentrator, zinc leaching plant, zinc purification plant and the manganese flotation plant. The phosphate plant was torn down in 1971 and the sponge iron plant will be torn down in the near future. The three acid plants once processed gases from the zinc roasters that are no longer operating (9).

2. Hydrometallurgical Plant (Arbiter Plant)

This new plant was evaluated in a separate Environmental Impact Statement prepared by the Air Quality Bureau, Montana State Department of Health and Environmental Sciences and issued in December, 1973. A complete description of the process is contained in that document and is only briefly outlined here. Startup of this plant is expected to be late in 1974.

The hydrometallurgical plant was designed to produce 6 million pounds of anode copper per month. The copper concentrates, pumped to the plant as a slurry, are diluted with process liquor and agitated in pressure vessels in the presence of oxygen and ammonia. The product, a slurry containing copper amine sulfate solution, passes through thickeners where the solid material is removed. The solid material then goes to flotation cells where metal values are separated from the waste. The flotation tailings and waste gypsum from another part of the process are combined and pumped to a tailings reservior as a slurry.

The copper amine sulfate solution is stripped of its copper content in a solvent extraction process. This copper rich solvent is mixed with spent electrolyte where it gives up the copper to produce enriched electrolyte. The strong electrolyte is pumped to the electrowinning building for electrolytic plating of the copper onto lead anodes. The spent solvent is recycled to pick up more copper from the copper amine sulfate solution.

Small portions of the spent electrolyte and leaching solutions are removed and neutralized with milk of lime to maintain proper component balances. The waste material, calcium sulfate, is mixed with the flotation tailings for disposal.

Important auxiliary equipment required for this process include the ammonia vent system, oxygen plant, boiler plant, and anode casting facility.

The ammonia vent system removes ammonia discharged from equipment containing strong solutions and passes these gases through a fractionating tower or wet scrubber before discharging the cleaned gases to the atmosphere.

The oxygen plant was designed and will be built and operated by Linde Division of Union Carbide Corporation. It will be capable of producing 115 T./day of gaseous oxygen and 5 T./day of liquid oxygen.

The boiler plant will have 3 boilers, each capable of producing 90,000 lbs/hr of steam at 125 pounds per square inch gage (psig). Each of two smaller boilers will produce 6,000 lbs/hr of steam at 850 psig. One boiler of each size will be a standby unit. All boilers will be fired with natural gas.

Since this is a new process, plant emissions can only be predicted. Sulfuric acid mist from the roof vents of the electrowinning building, ammonia from the wet scrubber and sulfur oxides and nitrogen oxides from the boilers are expected. All such emissions will be minimal, however, because of the solubility of effluents and the design of the facilities.

B. Sources of Pollution

1. Sulfur Oxides

The reverberatory furnaces and the converters generate nearly all of the sulfur oxides now emitted from the Anaconda smelter.

About 38% or 438 T./day of the sulfur oxides generated at the smelter come from the reverberatory furnaces (3). Here the sulfur dioxide concentrations are low due to dilution with fuel combustion gases and are not normally suitable for acid plant feed (4). All of these gases discharge directly to the main stack with no sulfur dioxide removal.

The converters generate approximately 700 tons per day of SO_2 (Appendix B), some 67% of which is removed in a 660 T./day sulfuric acid plant. The other 30-40% passes through the flue system to the main stack. The hoods on the converters collect only about 95% of the gases generated by the converters; the remaining 5% escaping into the building and exhaust via roof ventilation fans to the outside atmosphere (3,10).

Smaller quantities of sulfur oxides emit from the tapping of slag and matte.

The roasters presently function only to dry the incoming smelter feed and emit almost no sulfur oxides.

2. Particulate

The many particulate emission sources at the Anaconda smelter include reverberatory furnaces, converters, roasters, casting furnaces, lime kilns, foundry, crusher and the two quarries.

The main stack releases large quantities of particulate generated at the reverberatory furnaces and converters into the atmosphere. These particulates are mainly oxides of heavy metals, including zinc, arsenic, lead, copper, etc. (8, 11). Sulfates may also exist as primary or secondary pollutants. The long flue leading to the stack acts as a settling chamber with some further particulate removal in an old electrostatic precipitator at the base of the stack. Estimated overall efficiency of these systems is 73% (8), leaving an emission of 31 T./day of particulate (2).

A baghouse with an estimated efficiency above 99% is now under construction to remove particulate from the reverberatory-converter off-gases.

The portion (about 67%) of the converter gases routed to the acid plant are thoroughly cleaned of particulate by a scrubber prior to entering the acid plant.

The drying operation now performed in one of the roasters releases only small amounts of particulate which are vented to a stack.

Gases from the two lime kilns at the Anaconda smelters are cleaned of particulate by scrubbers, with an estimated total aerial emission of 20 lbs/hr (6).

Casting furnaces emit combustion gases and only small amounts of particulate.

The foundry cupola furnaces operate for only 5 hours in every 10 days. During that operation large amounts of particulate are emitted. Emission rates have been measured at 255 lbs/hr (6).

C. History of Plant and Existing Control

The Clean Air Act of Montana (1967) declared: "The public policy of this state and the purpose of this act to achieve and maintain such levels of air quality as will protect human health and safety, and to the greatest degree practicable, prevent injury to plant and animal life and property, foster the comfort and convenience of the people, promote the economic and social development of this state and facilitate the enjoyment of the natural attractions of this state."

The State Board of Health was given the responsibility for administration of the act through the assistance of a Director of Air Pollution Control and subordinate employees. An Air Pollution Control Advisory Council consisting of the Executive Officer of the State Board of Health and ten members appointed by the Governor was created to advise the Board of Health. The administrative duties associated with the Act are now handled by The Air Quality Bureau of the Department of Health and Environmental Sciences.

The Board of Health with its power to "adopt, amend, and repeal rules implementing and consistent with the provisions of this Act" promulgated regulations 90-008, Sulfur Oxide Emissions and 90-015, Ambient Air Quality Standards in April, 1970 and November 1969, respectively. Another regulation, 90-007, Visible Air Contaminants, was adopted in stages from November, 1968 through June, 1970. All three regulations are included in Appendix A.

In 1971 The Anaconda Company requested a change in the state sulfur oxide regulation. On December 15, 1971, a lengthy public hearing before the State Board of Health was held, and the request was denied.

In January, 1972, Governor Anderson submitted the state's "Implementation Plan for Control of Air Pollution in Montana" to The Environmental Protection Agency (EPA) after deleting the section on sulfur oxide control. This action required EPA to promulgate its emission standards for the Anaconda smelter. The proposed EPA rules were published on July 27, 1972. A public hearing on these proposed rules was held in Helena in August, 1972. In September, 1972, The Anaconda Company filed suit against EPA for what they considered improper procedure prior to promulgating these rules. In December, 1972, the U.S. District Court in Denver rendered a decision favorable to the Company. In July, 1973, the U.S. Court of Appeals for the Tenth Circuit reversed the decision of the lower court.

In June, 1973, the U.S. Supreme Court upheld lower court rulings that EPA must disapprove all state implementation plans which did not contain provisions to prevent significant degradation of existing air quality in areas that had cleaner air than allowed by the national standards. In September, 1973, EPA held the first public hearing on how to achieve "no significant degradation" of air quality.

The Anaconda Company was granted a one-year variance for the smelter particulate emissions in July, 1973. About the same time the Company began construction of a new baghouse for control of these emissions. The Anaconda Company's 1972 Annual Report states "The State of Montana has promulgated an emission standard of the same magnitude as the one proposed by the federal agency. This standard is scheduled to go into effect on July 1, 1973, and Anaconda will seek relief from its enforcement." The regulation was effective June 30, 1973. On June 30, 1973, the Company's present variance petition was filed.

Copper production at the Anaconda smelter since 1966 has increased from 25.9 million pounds per month (lbs/mo) to the present capacity of about 35 million lbs/mo (14). Since 1967 changes in the copper production facilities (9) have been made by:

1. Eliminating zinc roasting in roaster building no. 2 in 1972 and changing from copper roasting to drying in 1971.
2. Increasing the number of converters from 6 in 1969 to 8 at the present time.
3. Increasing from 2 to 4 casting furnaces in 1972 and from 1 to 2 casting wheels at the same time.
4. The E. Anaconda crusher, previously used on a one or two day per week schedule, started processing Continental East ore at a daily double shift rate of 14,000 tons in November, 1973.
5. The original copper concentrator was reactivated in November, 1973, to process copper ore from the E. Anaconda crusher.

The new 660 T./day sulfuric acid plant and associated water-cooled converter hoods, ducts, and gas scrubber were installed from 1971-1973 to produce sulfuric acid from the converter off-gases. As of December, 1973, the acid plant was not being operated at full capacity (12). Use of this system will remove particulate matter and sulfur oxides from about 67% of the existing converter off-gases. The reduction in emissions when this plant reaches full production will be about 436 tons per day of sulfur dioxide.

The electrostatic precipitator at the base of the main stack has been the primary particulate control device at this smelter since 1918. It is still in use but probably will be discontinued about 1977 when the new baghouse and the proposed electric smelting furnace are completed. The baghouse is now under construction and should treat a portion of the reverberatory furnace and converter off-gases by 1975. No construction schedule for the electric furnace has been announced.

Lime kiln no. 1 was built in 1955 to produce burnt lime and milk of lime (9). The original pollution control equipment consisted of a settling chamber in the flue system. A Notice of Violation from the State Air Quality Bureau for excessive emissions from this facility was served upon the Company in February, 1973. The problem which caused that Notice was corrected by installing a Ducon wet scrubber in series with the settling chamber.

Lime kiln no. 2 was built in 1940-41 for use as a manganese nodulizing plant. This service was discontinued in 1964. It is now used as a lime kiln (9). The Company also received a Notice of Violation in February, 1973, for excessive emissions from this plant. That problem was also corrected when the Company installed water sprays in a section of the exhaust flue.

Roaster building no. 1 has been used as a concentrate storage facility since about 1958. It may be phased out of operation by about 1976 (9).

Roaster no. 2 was constructed about 1915. Roasting of concentrates was stopped in 1972 but the facility is now used to dry copper concentrates (9). The two electrostatic precipitators and gas scrubber used to clean the flue gases from the facility when it was used as a roaster are now idle. Combustion gases from the concentrate drying are vented to the atmosphere without being cleaned.

The foundry was built about 1900 to fabricate parts for both the Butte and Anaconda operations. It is now used to provide the smelter with castings which cannot be purchased elsewhere (9). The emissions from the furnaces during charging violate state standards. The Company received a Notice of Violation for these emissions in February, 1973, with a requirement for correction by August 1, 1973. As of January, 1974, the Company has not reported any corrective action taken.

The silica and limestone quarries were both opened about 1900, and have been in continuous service ever since (9).

Zinc production ceased during the 1969-74 period (9). The following events took place:

1. The zinc leaching and purification plants were closed in 1969.
2. The three sulfuric acid plants treating zinc roaster off-gases were shut down in June, 1972.
3. Zinc roasting in roaster building no. 2 was discontinued in 1972.
4. The zinc plant at Great Falls closed in 1972.
5. The zinc crusher building was torn down in 1973. The zinc concentrator is idle but still usable for either zinc or copper concentration.

Manganese nodules were produced at this plant from the beginning of World War II until 1959 (9). This was started by request of the federal government but continued some time after that conflict had ended. This plant has been idle since 1959.

The phosphate plant construction started in 1948, and operations ceased in 1961. During this time, sulfuric acid made from zinc roaster off-gases was used to produce ammonium phosphate and treble super phosphate fertilizers and vanadium oxides. Much of this plant has been dismantled since 1961. The three sulfuric acid plants, with a total acid capacity of 450 T./day, are now idle but still usable (1,9).

Sponge iron, used as a precipitating agent in the copper leaching process, was manufactured at Anaconda from 1951 until 1961. This plant may be demolished in 1974 (9).

The arsenic plant was constructed about 1918 and its use discontinued in 1964 (9).

D. Sulfur Dioxide Control Techniques

In this section on control techniques all single-spaced material including all tables and figures are taken directly from the U. S. Environmental Protection Agency (EPA) document "Background Information - Proposed New Source Performance for Primary Copper, Zinc and Lead Smelters, 1973."

Notations as to sources of material for this document have been deleted from the quotes.

4. Control Techniques

4.1 Sulfuric Acid Plants

4.1.1 Summary

"The most common technique for control of emissions of sulfur oxides from copper, lead, and zinc smelters is catalytic oxidation of sulfur dioxide in the smelter off-gases to sulfur trioxide for the production of sulfuric acid. Contact sulfuric acid plants can be designed to produce acid from gas streams containing from a fraction of a percent of sulfur dioxide up to the highest concentrations feasible in smelting operations. However, economic considerations usually restrict the applications to concentrations ($> 3\frac{1}{2}$ or 4%) which allows autogenous operation.

"Sulfuric acid mist and smelter off-gas contaminants can present difficulties in the production of sulfuric acid due to corrosion of heat exchanger tubes, plugging of catalytic beds, or partial deactivation of the catalyst. These difficulties can be minimized by adequate design and proper maintenance of the gas purification system and the acid plant. However, an EPA analysis indicates that a 30% increase in sulfur dioxide emissions can occur due to catalyst deterioration between annual catalyst screenings.

"It is widely accepted that fluctuations in inlet volumetric flow rates and sulfur dioxide concentrations adversely affect sulfur dioxide emissions from sulfuric acid plants, although no data exists to quantify these affects. An EPA analysis, however, indicates that averaging sulfur dioxide emissions over a time period of six hours effectively masks normal short-term fluctuations in sulfur dioxide emissions.

"Sulfuric acid plant vendors guarantee maximum sulfur dioxide emissions concentrations of 2000 ppm for metallurgical single-stage absorption plants and 500 ppm for metallurgical dual-stage absorption plants during three to five-day new plant performance tests. These guarantees are for maximum sulfur dioxide emissions and include inherent allowances for increased emissions due to inlet sulfur dioxide fluctuations. However, these guarantees do not include allowances for increased emissions due to catalyst deterioration.

"Manufacturers of acid mist eliminators guarantee maximum stack emissions of 1 mg/ft^3 for high efficiency acid mist eliminators. These manufacturers do

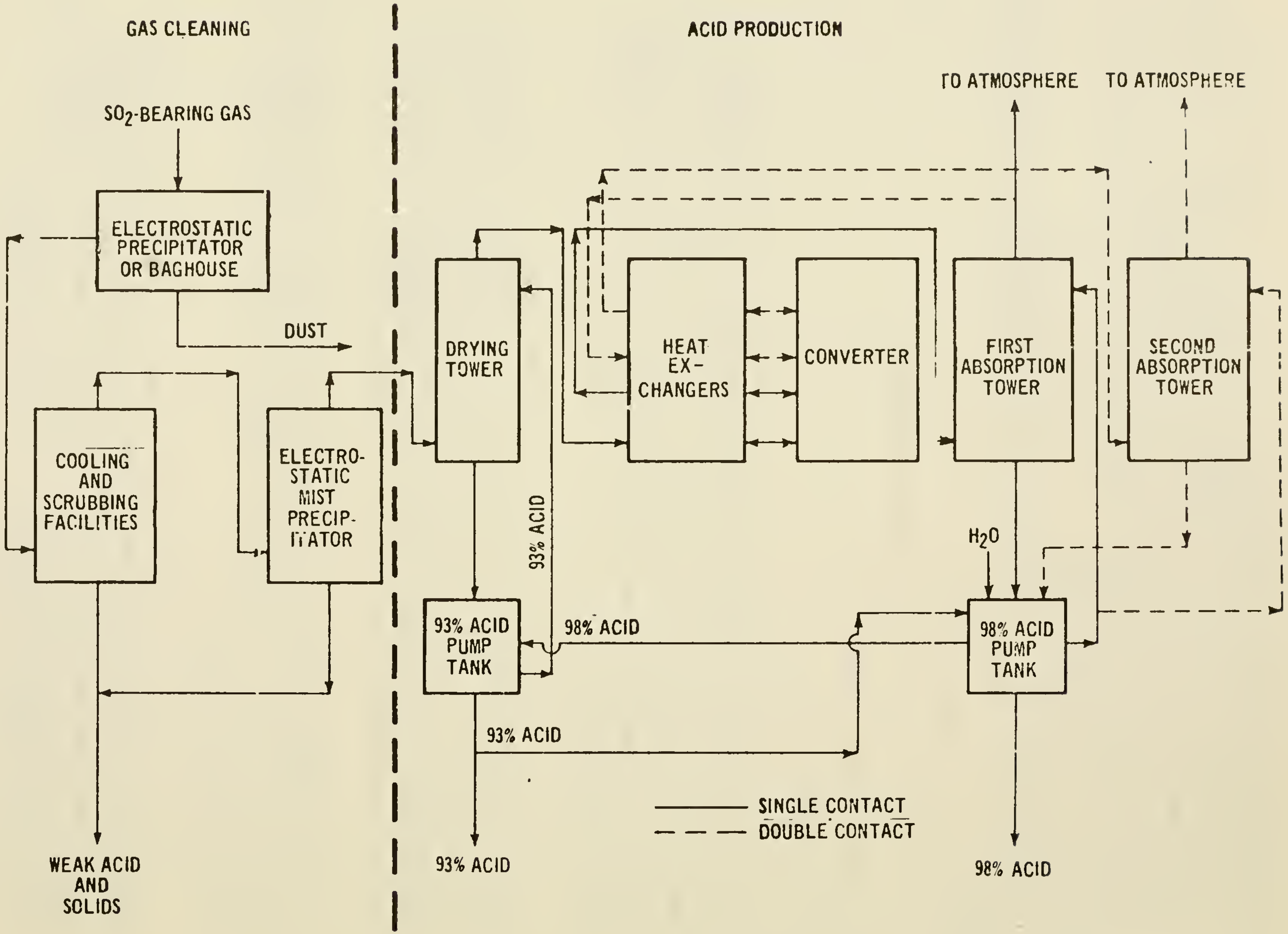


Figure 4-1 Sulfuric acid plant.

not guarantee any form of visible emission limitation, but acid mist emissions of 1 mg/ft^3 normally result in stack plumes of less than 10% opacity. Thus, present control technology is adequate to restrict acid mist emissions to low opacity wisps, except during infrequent upsets."

4.1.2 General Discussion

"The basic steps in the contact process for the manufacture of sulfuric acid from sulfur dioxide-bearing gases are shown schematically in Figure 4.1. The off-gases are cooled and cleaned to remove particulates and volatile metals, acid mist is removed in an electrostatic mist precipitator and the gases are dried with 93% sulfuric acid. The cool, dry gases then pass through a series of gas-to-gas heat exchangers to heat the off-gases to the optimum temperatures for catalytic conversion of sulfur dioxide to sulfur trioxide (SO_3). Single-stage absorption acid plants use three or four stages of converter catalyst, whereas dual stage absorption plants use one, two, or three stages of catalyst before the first absorption tower. Since the conversion of sulfur dioxide to sulfur trioxide is exothermic, the converter outlet gases must be cooled before passing through the absorption tower. These outlet gases are passed countercurrent to the inlet gases in the heat exchangers mentioned above. The sulfur trioxide is then absorbed by 98% sulfuric acid in an absorption tower to yield the product. The remaining gases are then treated to remove acid mist and spray, and vented to the atmosphere if a single-stage absorption acid plant is employed. In a dual-stage absorption acid plant, the gases exhausted by the first absorption tower are passed through a second series of heat exchangers and catalytic converter stages to oxidize the sulfur dioxide remaining in the gases. Normally, this step employs one or two stages of catalyst. The gases then pass through a second absorption tower where sulfur trioxide is absorbed by sulfuric acid as in the first absorption tower. The waste gases are then treated to remove acid mist and spray, and vented to the atmosphere.

"Specific design parameters, such as the number of converter stages, catalyst inlet and outlet gas temperatures, and the degree of sulfur dioxide conversion in each catalyst stage, are based on reaction kinetics and equilibrium considerations. In dual-stage absorption acid plants, the removal of sulfur trioxide in the first absorption tower shifts the sulfur dioxide/sulfur trioxide equilibrium in favor of formation of more sulfur trioxide and results in significantly less unconverted sulfur dioxide.

"Although a gas stream containing more than 3½% sulfur dioxide is a prime consideration for acid production in single-stage absorption acid plants and a gas stream containing more than 4% sulfur dioxide is a prime consideration in dual-stage absorption acid plants, these considerations are not due to technical limitations. Contact sulfuric acid plants can be designed to produce acid from gases containing a fraction of a percent of sulfur dioxide. Economic considerations, however, usually restrict the applications to higher concentrations, since operating costs rise rapidly as the concentration of sulfur dioxide decreases.

"From mid-1971 until the end of 1972, however, the Onahama Smelting and Refining Company copper smelter in Japan produced concentrated sulfur acid from the off-gases of a green-charged reverberatory smelting furnace. At this smelter, a pre-existing single-stage sulfuric acid plant was redesigned to treat weak sulfur dioxide off-gases as low as 1.5% sulfur dioxide (averaging 2.5% sulfur dioxide), while maintaining a conversion efficiency of almost 97%.

Operation on such low sulfur dioxide concentrations required that the smelting furnace off-gases be refrigerated to approximately 15°C and dried to prevent exorbitant dilution of the product acid. The cooled and dried gas then required reheating to maintain optimum catalyst converter temperatures.

"Although this acid plant is no longer in operation, it was not shut down as a result of technical problems that developed. Onahama Smelting and Refining expanded the smelter by the construction of an additional reverberatory smelting furnace and additional copper converters. The acid plant now controls sulfur dioxide emissions from the new copper converters. A prototype magnesium oxide (MgO) gas scrubbing system, developed by Onahama Smelting and Refining, controls sulfur dioxide emissions from the reverberatory smelting furnaces.

"Gases containing less than 4% sulfur dioxide frequently require extra cooling in the gas purification system to remove excessive water vapor, and gases containing less than 3% sulfur dioxide frequently require refrigeration to condense enough water to obtain an acceptable water/sulfur ratio. A low water/sulfur ratio in the gases is necessary since excessive water remaining in the gas will cause dilution of the product acid below commercial grade strength.

"Single-stage sulfuric acid plants are not able to operate autothermally on off-gas streams containing less than 3½% sulfur dioxide, and dual-stage absorption acid plants require off-gases with a sulfur dioxide concentration somewhat higher (about 4%) to operate autothermally. Acid plants normally contain fired heaters for start-up operation. However, if off-gases containing less than 3½% sulfur dioxide, or 4% sulfur dioxide in the case of dual-stage acid plants, are processed on a continuous basis, large fired heaters for continuous operation to heat the gases to the temperatures necessary to obtain rapid and effective conversion of sulfur dioxide to sulfur trioxide must be incorporated.

"On the other hand, gases with sulfur dioxide concentrations of 7% or more usually do not contain sufficient oxygen for the conversion of sulfur dioxide to sulfur trioxide. It is necessary to dilute these gases with air or other off-gases containing excess oxygen before the gases enter the acid plant converters to provide the proper ratio of oxygen to sulfur dioxide.

"For maximum operating efficiency, metallurgical sulfuric acid plants should operate on a gas stream of uniform flow rate and sulfur dioxide concentration, such as those from roasters or smelting furnaces. Gas streams of fluctuating flow rates and sulfur dioxide concentrations, such as those from copper converters, require acid plants to be designed for the worst conditions and with adequate controls to handle variations in sulfur dioxide concentrations. Variations in feed gas volume are less of a problem and can be tolerated within reasonable limits.

"In order to reduce the cost of sulfur recovery, proper design necessitates that gas volumes be minimized and sulfur dioxide concentrations be maximized as much as is practical. Effective methods of increasing the sulfur dioxide concentration include oxygen enrichment of combustion air and the reduction of air infiltration by using tight-fitting hoods. Use of such methods increased the sulfur dioxide content of the off-gases from the Onahama reverberatory smelting furnace previously mentioned by approximately 50%.

"The presence of high levels of solid or gaseous contaminants in smelter off-gases can present difficulties in the production of sulfuric acid. In general, these contaminants are removed from the gas stream prior to the catalyst converters. Their reclamation represents an economic recovery or prevents damage to the acid plant or contamination of the product acid. The off-gases from smelting operations contain varying amounts of entrained dust as well as fumes formed by vaporization and subsequent condensation of volatile components. This includes compounds of arsenic, antimony, cadmium, mercury, etc., in addition to copper, lead, and zinc.

"Most of the dust and fume is recovered in dry-type collectors, such as cyclones, electrostatic dust precipitators, and baghouses, for its economic value. However, in many cases, additional cleaning is required to remove residual quantities in order to protect the acid plant. The major problems caused by these residual quantities include plugging of the catalyst beds with deactivation of the catalyst and contamination of the product acid. Chlorine and fluorine attack of stainless steels and perforation of lead sheathing by small amounts of mercury also present difficulties. However, anticipation of the potential magnitude of these problems, followed by installation of adequately designed gas cleaning systems, will ensure reduction of the concentrations to tolerable levels.

"Table 4.1 contains estimates of the maximum levels of impurities that can be tolerated in smelter off-gases. The degree of catalyst deterioration experienced at these various impurity levels can be accommodated by an acid plant which shuts down once per year to screen the catalyst and repair equipment. Table 4.1 also contains the estimated upper level of impurities that can be removed by typical gas purification systems with prior coarse dust removal. Although complete removal of contaminants from the off-gases is not practical, 99.5 to 99.9% overall removal is considered to be attainable. For especially severe cases of contamination, more elaborate cleaning systems must be designed specifically for the problem contaminants. The details vary with the contaminants, but the general solution includes the use of more efficient dust or mist collectors and the scrubbing of the gases with liquids which absorb the contaminants.

"Although it is widely accepted that metallurgical off-gas contaminants can lead to plugging of the catalyst beds or partial deactivation of the catalyst, there exists a general lack of substantial numerical qualification of the effect of catalyst deterioration on sulfur dioxide emissions from metallurgical sulfuric acid plants. Sulfur dioxide emission data gathered by simultaneous EPA source testing of the No. 6 and No. 7 single-stage acid plants at the Kennecott Garfield smelter during the period of June 13-16, 1972, however, indicate that normal catalyst deterioration can result in a 30% increase in sulfur dioxide emissions.

"At the time of the EPA source testing, the No. 6 (Parsons) plant was in the second month of its twelve-month catalyst cleaning cycle and the No. 7 (Monsanto) plant was in the twelfth and last month of its catalyst cleaning cycle. A statistical analysis of the emission data leads to the conclusion that the 30% greater average emissions of the No. 7 plant, compared to the average emissions of the No. 6 plant, are statistically significant at the 90% probability level. This difference in emissions reflects not only catalyst deterioration but also other factors, such as differences in emissions due to design or construction variations between Parsons 1967

Table 4-1 ESTIMATED MAXIMUM IMPURITY LIMITS FOR METALLURGICAL OFF-GASES USED TO MANUFACTURE SULFURIC ACID[10]

	Approximate Limit, (Mg/Nm^3)[a]	
Substance	Acid Plant Inlet	Gas Purification System Inlet[b]
Chlorides, as Cl	1.2	125[d]
Fluorides, as F	0.25	25[e]
Arsenic, as AS_2O_3	1.2[c]	200
Lead. as Pb	1.2	200
Mercury, as Hg	0.25	2.5[f]
Selenium, as Se	50[c]	100
Total Solids	1.2	1000[g]
H_2SO_4 Mist, as 100% acid	50	-
Water, as H_2O	-	400×10^3

Notes:

(a) Basis: dry off-gas stream containing 7% sulfur dioxide.

(b) For a typical gas purification system with prior coarse dust removal.

(c) Can be objectionable in product acid.

(d) Must be reduced to 6 if stainless steel is used.

(e) Can be increased to 500 if silica products in scrubbing towers are replaced by carbon; must be reduced if stainless steel is used.

(f) Can be increased to 5-12 if lead ducts and precipitator bottoms are not used.

(g) Can usually be increased to 5000-10,000 if weak acid settling tanks are used.

acid plant technology and Monsanto 1970 acid plant technology. However, it is safe to assume that the major portion of this difference in emissions is due to catalyst deterioration.

"Although additional data are not available, metallurgical sulfuric acid plant vendors have agreed that the EPA estimate of a 30% increase in SO_2 emission concentrations as the upper limit for deterioration of catalyst performance between catalyst screenings for single-stage acid plant is also a reasonable estimate for dual-stage acid plants. The period between catalyst screenings is primarily a function of pressure drop rather than conversion efficiency. Generally, the first bed depth is 50% greater than the theoretical design depth in order to compensate for the anticipated decrease in conversion efficiency as the catalyst becomes partially plugged and the pressure drop increases between catalyst screenings. Catalysts are guaranteed for various periods although longer guarantees necessitate the use of more catalyst for a larger conversion efficiency margin. The screening period varies from one year to two years depending upon blower capacity and the particulate collection efficiency of the gas purification equipment. As a rule of thumb, for an application in which the catalyst is not subject to poisoning, the catalyst in the first bed should be replaced after 10-12 years if performance has deteriorated.

"Acid plant vendor guarantees are based on new plant performance and do not include a margin for increases in emissions due to catalyst or plant deterioration with age. Furthermore, these guarantees are for acid plant performance only and obviously do not include smelter emissions which are bypassed to the atmosphere during periods of acid plant shutdown for catalyst screening and/or replacement or other plant maintenance.

"In some cases, trace amounts of contaminants can pass through both the gas cleaning equipment and the catalyst to contaminate the product acid. In these cases, the acid can either be sold to outlets that are not sensitive to the contamination, cleaned of the objectionable contamination, or neutralized and disposed of. The production of dark, discolored acid ("black acid") is a common example of acid contamination. Frequently, within multi-hearth roasters or lead sintering machines, various organic agents entrained with the concentrates are merely vaporized or only partially decomposed. Trace amounts of these organic agents can pass through both the gas cleaning equipment and the catalyst and be captured in the product acid leading to the production of "black acid".

"Normally, within fluid-bed roasters, however, these organic flotation agents are completely decomposed and thus sulfuric acid produced from these off-gases is free of organic contaminants. Although there are techniques which can be used to purify or bleach acid, these techniques are usually costly and sometimes are not entirely satisfactory. For example, oxidation of the organic contaminants by hydrogen peroxide is accompanied by the release of water which dilutes the product acid. Similarly, the use of potassium permanganate results in the contamination of the acid by manganese ions which can be objectionable in some processes. Experiments have been conducted using ozone as the oxidizing agent and the results are promising. However, there are outlets for sulfuric acid which are not sensitive to color, such as the production of fertilizers or alkylation processes at refineries.

"Contamination of product sulfuric acid by other contaminants, such as mercury, cadmium or arsenic, etc., can also occur. In general, these contaminants are more difficult to remove from the product acid and present greater problems than the production of "black acid." Although the Bunker Hill Company recently announced development of a process capable of reducing mercury levels in sulfuric acid from 100 ppm to 1 ppm [sic.]

"Depending upon the amount of excess oxygen, the temperature, and the presence of metallic oxide particulates in the off-gases, some sulfur trioxide is formed during the various smelting operations. In the presence of water or weak acid vapors, sulfur trioxide forms sulfuric acid mist at temperatures of less than 200°C. If not removed, the mist particles will cause corrosion problems and the iron sulfates resulting from corrosion can be deposited on the catalyst. Heat exchanger corrosion is serious, not only because of the physical damage to the equipment, but also because leaks will result in a substantial increase in the concentration of sulfur dioxide contained in the gas stream to the final absorber. This sulfur dioxide is not absorbed and is emitted to the atmosphere.

"Sulfuric acid mist particles are extremely difficult to remove from the gas stream, and special equipment, such as electrostatic mist precipitators, are required. To guard against small amounts of dust or mist which can be carried through precipitators due to flow surges or other troubles, a fiber bed filter, such as the Brink Mist Eliminator, can be used as a backup device. Although maintenance benefits and corresponding sulfur dioxide emission abatement benefits can be realized by using fiber bed filters ahead of heat exchangers and catalyst states, such installations are still infrequent. However, fiber filters have been widely accepted for removal of sulfuric acid mist from absorber effluents, and they can be utilized to protect process equipment. In general, by adequate plant design and proper maintenance, the effects of corrosion due to acid mist can be minimized. Furthermore, due to the use of special linings, demisters, and special alloy heat exchanger tubes, sulfuric acid plants are currently being designed to have extremely long life and low maintenance.

"Acid mist emissions from dual-stage sulfuric acid plants are normally less than acid mist emissions from single-stage acid plants because the mist loading of the final absorbing tower is less. However, an acid mist eliminator must be installed following the first absorption tower in dual-stage acid plants to protect downstream equipment from corrosion. Absorption towers have inherent lags and are extremely sensitive to many variables including inlet sulfur trioxide concentration, absorbing acid strength, temperature, and flow rate. However, present control technology is adequate to restrict acid mist emissions to low opacity wisps, except for infrequent upsets. Such upsets are caused by the absorbing sulfuric acid concentration becoming greater than azeotropic and thus allowing sulfur trioxide to remain unabsorbed by the acid and create a visible acid mist plume as it combines with water after leaving the stack. Mist eliminators are particulate collection devices and obviously cannot prevent acid mist emissions produced during upsets by combination of sulfur trioxide emissions with water after leaving the mist eliminator.

"Manufacturers of mist eliminators guarantee maximum stack emissions of 1 mg/ft^3 for high-efficiency mist eliminators and 2 mg/ft^3 for lower efficiency models. Mist emissions are normally less than 50% of the guaranteed value.

> Under worst conditions the 2 mg/ft^3 emission value can represent a 20% opaque plume, but normally the emissions from a high-efficiency mist eliminator are less than 10% opacity.
>
> "Typically, sulfuric acid plant vendors guarantee maximum sulfur dioxide emission concentrations of 2000 ppm for metallurgical single-stage absorption plants and 500 ppm for metallurgical dual-stage absorption plants during new plant performance tests. Such tests are conducted for three to five consecutive days while the plant is operating on gases that contain the percentages of sulfur dioxide specified in the design basis for the plant and while the plant is not experiencing any malfunctions. It is significant to note that these guarantees are for maximum sulfur dioxide emissions and thus include inherent allowances for increased emissions due to inlet sulfur dioxide fluctuations. Although these guarantees are for new plants and do not include allowances for increases in emissions due to catalyst or plant deterioration with age, one domestic vendor does guarantee these emission levels for one year after start-up.
>
> "An EPA analysis of approximately ten weeks of emission data from one of the Kennecott Copper Corporation single-stage sulfuric acid plants at Garfield, Utah, showed sulfur dioxide emissions during normal operations of less than 2000 ppm when averaged for long periods, such as one week. The specification of 'normal' operations was determined by analyzing acid plant operating logs and inlet flow rate and sulfur dioxide concentration data to ascertain the extent of malfunctions and startup and shutdowns during the period. It is significant to note that the long term average SO_2 concentration value is considerably less than the emission concentration (2700 ppm) corresponding to the vendor guarantee of 95% conversion at 5% SO_2 inlet.
>
> "For maximum operating efficiency metallurgical sulfuric acid plants should operate on gas streams of uniform flow rate and sulfur dioxide concentration. However, off-gases from some smelting operations, such as copper converting, exhibit extreme fluctuations in both volumetric flow rate and sulfur dioxide concentration."
>
> "The use of sulfuric acid plants to control sulfur dioxide emissions from copper, lead and zinc smelters in well demonstrated technology. As discussed in Section 5 of this document, six of the fifteen domestic copper smelters produce sulfuric acid from process off-gases. All of these acid plants are of the single-stage absorption design."

Neutralization of smelter produced sulfuric acid may be required if ready markets or uses for the acid are not found. As of this time neutralization for this purpose is almost non-existent and it is possible new markets may develop for available cheap sulfuric acid.

Limestone likely would serve as the most practical agent for neutralization. On a stoichiometric basis, one mole of limestone would be required to neutralize 1 mole of sulfuric acid; and in turn 1 mole of $CaSO_4$ would be produced. Without careful system design, sulfuric acid neutralization would result in solid waste disposal problems and possibly contamination of water with soluble magnesium salts. As mentioned above, neutralization may be unnecessary and if employed may be used on only a partial or standby basis.

4.2 Elemental Sulfur Plants

4.2.1 Summary

"Elemental sulfur plants have never achieved widespread use within the copper, lead or zinc smelting industry. However, in some cases they represent a viable alternative to the production of sulfuric acid from sulfur dioxide emissions contained in various smelter off-gases. Three companies have developed or are actively developing sulfur dioxide reduction technology: Allied Chemical Corp. and American Smelting and Refining Co./Phelps-Dodge Corp. (ASARCO/PD) in the United States and Outokumpu Oy in Finland. Both Allied Chemical and Outokumpu have announced the commercial availability of their technology. ASARCO/PD, however, is still in the pilot plant stage of development.

"The Allied Chemical and ASARCO/PD technology is generally applicable to the wide range of smelter off-gases. The Outokumpu technology, however, is restricted to flash smelting furnaces.

"Of the various off-gases generated during the smelting of copper, lead or zinc, only those discharged by fluid-bed roasters and flash smelting furnaces are suitable for direct application of sulfur dioxide reduction technology. Off-gases discharged by other process units require concentration of the sulfur dioxide in a regenerative off-gas desulfurization system prior to reduction.

"There exists little data from which a quantitative conclusion can be drawn regarding the increase in sulfur dioxide emissions from elemental sulfur plants due to normal catalyst deterioration. However, review of the limited data available indicates that 5-10% increase in emissions is likely to occur between annual plant turnarounds as a result of catalyst deterioration.

"Elemental sulfur plants normally achieve sulfur dioxide reduction efficiencies of 90%. The concentration of sulfur dioxide in the tail gases released to the atmosphere is normally in the range of 0.7-1.0%, if the plant operates on the off-gases from a fluid-bed roaster or flash smelting furnace. If the plant operates on a sulfur dioxide process gas produced by a regenerative off-gas desulfurization process, the concentration of sulfur dioxide in the tail gas released to the atmosphere is normally in the range of 2-5%."

Several processes for clean-up of tail gas streams from elemental sulfur plants are avaialble. These include Wellman and Beavon Sulfur Removal Process.

4.2.2 General Discussion

"Although elemental sulfur plants have never achieved widespread use within the copper, lead or zinc smelting industry, the recovery of elemental sulfur from smelter off-gases has generated a great deal of interest, as evidenced by the number of elemental sulfur plants that have operated throughout the world during the past forty years. The failure of this technology to achieve widespread application in most cases has not been due to technical limitations, but a matter of economics where other alternatives have been available.

"Essentially, elemental sulfur plants consist of two basic process steps. A fossil fuel is mixed with the gas stream to be reduced, frequently in the presence of a catalyst to promote the reduction reactions. A portion of the sulfur dioxide in the gas stream is reduced to elemental sulfur and hydrogen sulfide. The extent to which elemental sulfur and hydrogen sulfide are formed and sulfur dioxide remains in the gas stream depends on temperature, pressure and the carbon to hydrogen ratio in the fuel utilized as a reductant. With the reductant properly proportioned to the sulfur dioxide in the gas stream, the ratio of hydrogen sulfide to sulfur dioxide remaining will be approximately 2:1. Following reduction, a Claus catalyst is utilized to react the hydrogen sulfide formed with the remaining sulfur dioxide, producing elemental sulfur according to the familiar Claus reaction:

$$4H_2S + 2SO_2 \rightarrow 3S_2 + 4H_2O$$

"The reductant employed in elemental sulfur plants can be coke, pulverized coal, fuel oil, natural gas or reformed natural gas. Natural gas or fuel oil, however, is frequently the choice of reductant where available, as a minimum of facilities for introduction and admixture into the gas stream to be reduced are required.

"Currently, three companies have developed or are actively developing sulfur dioxide reduction technology for direct application to copper, lead or zinc smelters: Allied Chemical Corp. and American Smelting and Refining Co/ Phelps-Dodge Corp. (ASARCO/PD) in the United States and Outokumpu Oy in Finland. Although both Allied Chemical and Outokumpu have announced the commerical availability of their technologies, ASARCO/PD is still in the pilot-plant stage of development."

Figure 4-X and 4-Y illustrate the two commercially available elemental sulfur processes

"4.3 Scrubbing Systems

"Historically, there has been little economic incentive to desulfurize process off-gases containing sulfur dioxide in concentrations ranging from 0.05 to 3.5 percent. Process off-gases from fossil fuel-fired power plants, refinery sulfur recovery plants, sulfuric acid plants, and certain smelter process equipment such as reverberatory furnaces and sintering machines are included in this category. Until recently, there has been little demonstrated control of sulfur dioxide from these sources, except in areas affected by severe air pollution problems. The approach utilized to control sulfur dioxide in most instances has been to employ scrubbing systems to chemically react the SO_2 with liquid phase absorbents to yield sulfur compounds that can be either discar,ed, reprocessed, or sold directly as obtained for use in other industries. The term "scrubbing systems" has come into common usage when describing such chemical processes since each of the systems required the use of process equipment, i.e., a scrubber to promote gas phase mass transfer and/or chemical reaction rate.

"There are three major variations of scrubbing systems where the reactant is added to the scrubbing media as indicated below:

1. Non-cyclic system - This open-loop type of system has a throwaway product. The liquor stream has only one pass through the scrubber.

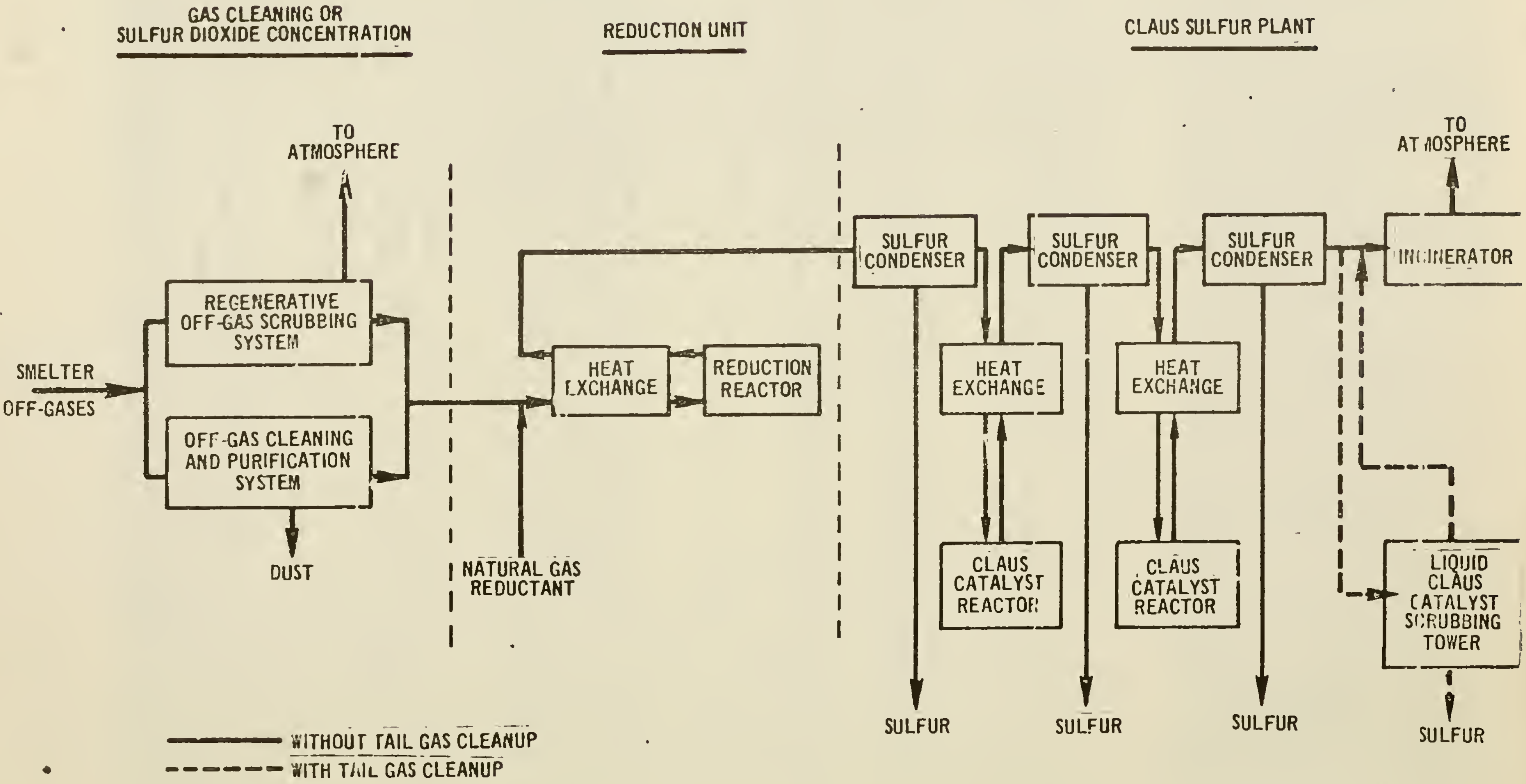


Figure [illegible] Allied Chemical Sulfur Dioxide Reduction Process.

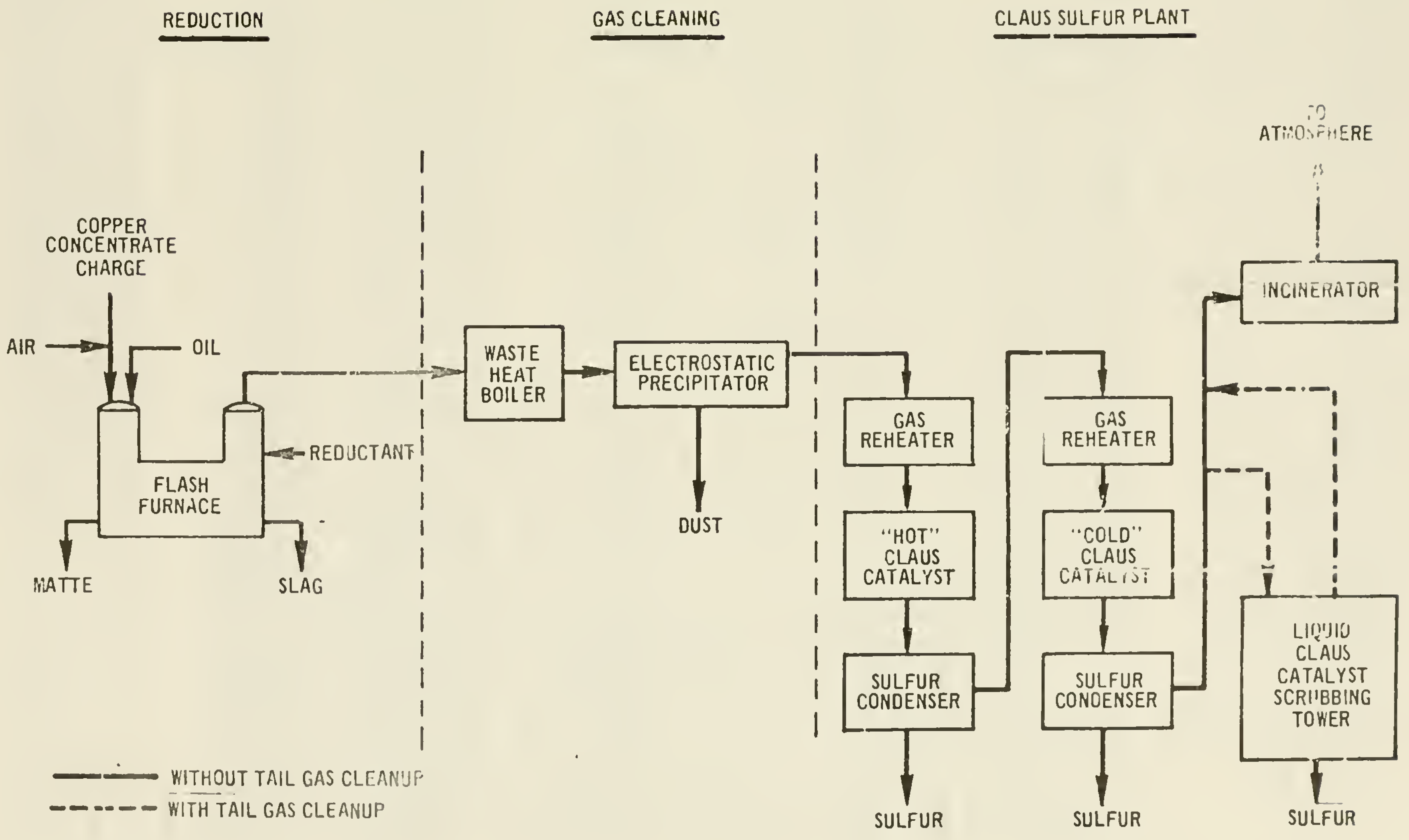


Figure 4-X: Outokumpu Sulfur Dioxide Reduction Process.

2. Cyclic-non regenerative system - This closed-loop type of system has a large percentage of the removed sulfur contained in a throwaway or salable product. As much as possible of the liquor stream is recycled through the scrubber. Depending on the process, SO_2 may or may not be recovered.

3. Cyclic-regenerative system - This closed-loop type of system recovers SO_2 and has a relatively small waste product for disposal. The absorbent is regenerated and the liquor stream recycled through the scrubber.

"The nature of metallurgical process off-gases is somewhat unique in that a wide variety of contaminants are included in the effluent stream along with sulfur dioxide. The presence of high concentrations of oxygen (relative to fossil-fuel-fired power generating plants), particulates, acid gases, metallic fumes, and high gas temperatures could cause chemical or mechanical problems with cyclic absorption systems. In most cyclic systems, pretreatment of the process off-gases would be required prior to absorption of the sulfur dioxide in the scrubbing media.

"During the past forty years, over fifty process schemes utilizing various types of absorbent as a scrubbing media have been investigated on a bench scale, pilot plant, or prototype basis in an effort to perfect the optimum control for low concentrations of sulfur dioxide in process off-gases. As a result of these efforts, at least two processes have emerged as worthy of commercial application in the control of low concentrations of sulfur dioxide in process off-gases from primary copper, lead and zinc smelters. These are the Cominco ammonia absorption process and the ASARCO DMA process. Two other processes that have had commercial application in the control of SO_2 from either fossil-fuel-fired power plants, sulfur recovery plants or sulfuric acid plants and are considered to have high potential in the control of low concentrations of SO_2 from smelter processes are calcium-based absorption systems and sodium sulfite-bisulfite absorption systems."

4.3.1 Calcium-Based Scrubbing Systems

"Calcium-based scrubbing systems may be of the non-cyclic type or of the cyclic-nonregenerative type. In the non-cycle system, the absorbent passes through the scrubber on a once-through basis. Early work on this type of system was conducted by the London Power Company in the 1930's, alkaline Thames River water provided the absorbent. This type of system has inherent water pollution problems in some situations that would preclude its usage on a wide scale.

"Also in the 1930's, technology was developed on cyclic-nonregenerative scrubbing systems. Lime-limestone (calcium based) processes were used on a commercial scale at the Fulham Power Station in England to control SO_2 emissions from power plant off-gases."

Summary

"There are no known installations of calcium-based scrubbing systems installed to control sulfur dioxide emissions from either domestic or foreign primary copper, lead or zinc smelters. However, facilities have been installed to control sulfur dioxide emissions from fossil-fuel-fired power plants, as well as a molybdenum ore roaster, a secondary lead smelter, and an iron ore sintering plant. All of these applications control process off-gases that have sulfur dioxide concentrations of less than 0.6 percent (6000 ppm). Although the smelter industry has not chosen to install calcium-based scrubbers to date it is pointed out that the use of calcium-based scrubbers to control sulfur dioxide from weak streams (0.6 to 3.0 percent) from primary copper, lead and zinc smelters has been suggested by organizations and individuals as documented below:

1. Arthur G. McKee & Company - in a report prepared for the Environmental Protection Agency, 1969.

2. The U. S. Bureau of Mines - in a report prepared to evaluate control of sulfur oxide emissions in copper, lead and zinc smelting, 1971.

3. Konrad T. Semrau, associated with Stanford Research Institute, in papers published in the Journal of the Air Pollution Control Association, 1971 and in the Journal of Metals, 1971.

4. Responsible control equipment vendors with years of research and experience with calcium-based scrubbing systems have indicated that higher concentrations of sulfur dioxide would not present unsurmountable operational problems."

Figure 4-2 illustrates the lime/limestone scrubbing process.

4.3.2 Dimethylaniline (DMA) Scrubbing

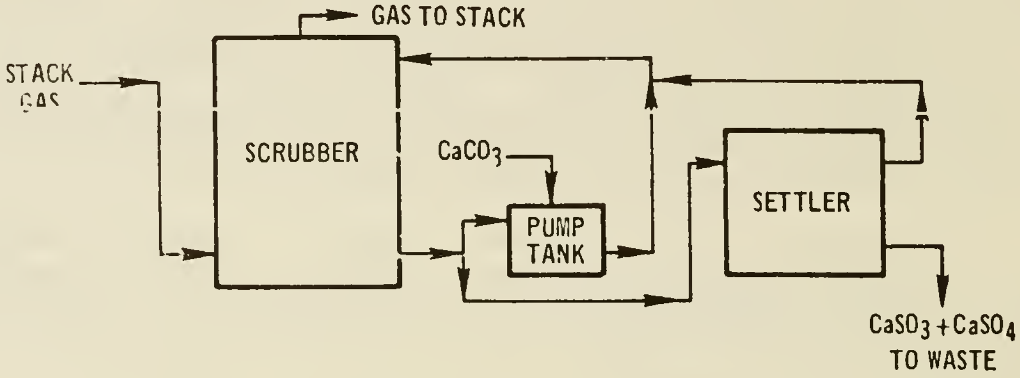
Summary

"The American Smelting and Refining Company dimethylaniline (DMA) process has been used to recover sulfur dioxide from smelter gases containing 4 to 10 percent sulfur dioxide. The process has been utilized to recover sulfur dioxide included in process off-gases emanating from Dwight-Lloyd lead sintering machines, and blended effluents from copper smelter roasters, reverberatory furnaces and conve-ters.

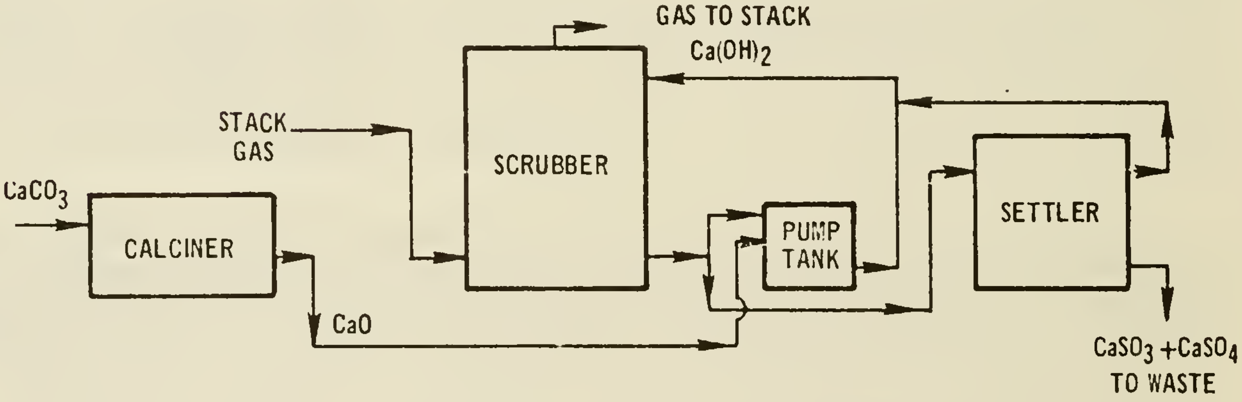
"A new DMA system was put into service in November, 1972, by Phelps-Dodge Corporation at Ajo, Arizona to recover sulfur dioxide from copper smelter reverberatory furnace and converter process off-gases. The system is reportedly designed to process reverberatory furnace off-gases with sulfur dioxide concentrations ranging from 1½ to 2 percent although proportional valving is installed so that converter gas can also be fed to the system. Although insufficient data are presently available to evaluate the Ajo facility when operated on copper smelter reverberatory furnace off-gases alone, it has been demonstrated in other applications that mixtures or blends of process off-gases from roasters, reverberatory furnaces and converters can upgrade the sulfur dioxide concentration of the feed stream to the DMA process so that the system can be operated in an acceptable manner.

"The equilibrium between dimethylaniline and sulfur dioxide is generally unfavorable for economic recovery of sulfur dioxide from gas streams containing less than 1.5 to 2.0 percent sulfur dioxide.

"It is concluded that the DMA absorption system is a viable process that can be utilized to control sulfur dioxide emissions from properly cleaned and



Scrubber addition of limestone.[6]



Scrubber addition of lime.[6]

Figure 4-2 Limestone/lime scrubbing processes.

conditioned smelter process off-gases that have (or can be upgraded to have) sulfur dioxide concentrations in the range of 4 to 10 percent.

"It is anticipated that the DMA system will be demonstrated in the near future for use on weak SO_2 streams from copper smelting operations."

Simplified Process Description

"The DMA absorption system is a cyclic-regenerative process. The system incorporates an absorption tower with numerous trays that allow for much greater gas phase mass transfer and reactant surface area than other scrubbers such as venturi or single-bed type. Liquid sulfur dioxide is recovered as a product, and the absorbent is regenerated and recycled through the system. A small purge stream is required to eliminate sodium sulfate (in solution) from the regenerator section. A small amount of dimethylaniline is also included in the purge stream.

"A simplified flow diagram for the dimethylaniline scrubbing system is depicted in Figure 4-3. A brief description of the process is essentially as follows. Pretreated SO_2 laden process off-gases vent to the bottom of a bubble plate scrubbing tower where most of the SO_2 is absorbed in a counter-current stream of anhydrous dimethylaniline. The gases, impoverished in sulfur dioxide and enriched in dimethylaniline vapors, then pass to a second section of the tower where they are scrubbed with a weak sodium carbonate solution. The residual SO_2 in the gases converts the sodium carbonate to sodium sulfite or sodium bisulfite. The carbon dioxide is liberated in the gas stream. The effluent gases then pass to a third section of the scrubbing tower where they are scrubbed with a weak sulfuric acid solution where entrained vaporized dimethylaniline is recovered as dimethylaniline sulfate. The effluent then vents to the atmosphere.

"Pregnant dimethylaniline is heated by exchange and then passes to the center section of a bubble plate stripping tower. The liquid flows downward countercurrent to a rising column of steam and sulfur dioxide vapors. The sulfur dioxide is stripped from the dimethylaniline and escapes upward through the tower. The recovered dimethylaniline is cooled and then passes to a series of separators where the absorbent floats on the water and can be physically separated and sent to the DMA surge tank for recycle.

"The aqueous effluent from the soda scrubbing and acid scrubbing sections of the absorption tower passes to a collection tank where dimethylaniline is liberated as a result of the reaction between dimethylaniline sulfate from the acid scrubber and the sodium sulfite-bisulfite from the soda scrubber. Part of the dimethylaniline remains dissolved in the water as dimethylaniline sulfite. Total water and solution added to the process empties to a stripper water tank. The water then passes to the bottom section (regenerator) of the stripping tower where the dimethylaniline sulfite is thermally decomposed and SO_2, DMA, and water are vaporized and vented into the stripper section of the tower. A small purge stream is drawn off the regenerator to remove sodium sulfate.

"The stripped SO_2 and residual DMA vapors pass from the stripping section into the top section (rectifier) of the stripping tower where they are bubbled through the water. The DMA, by reacting with SO_2 in the presence of water, is recovered as dimethylaniline sulfite and passes back to the stripper section.

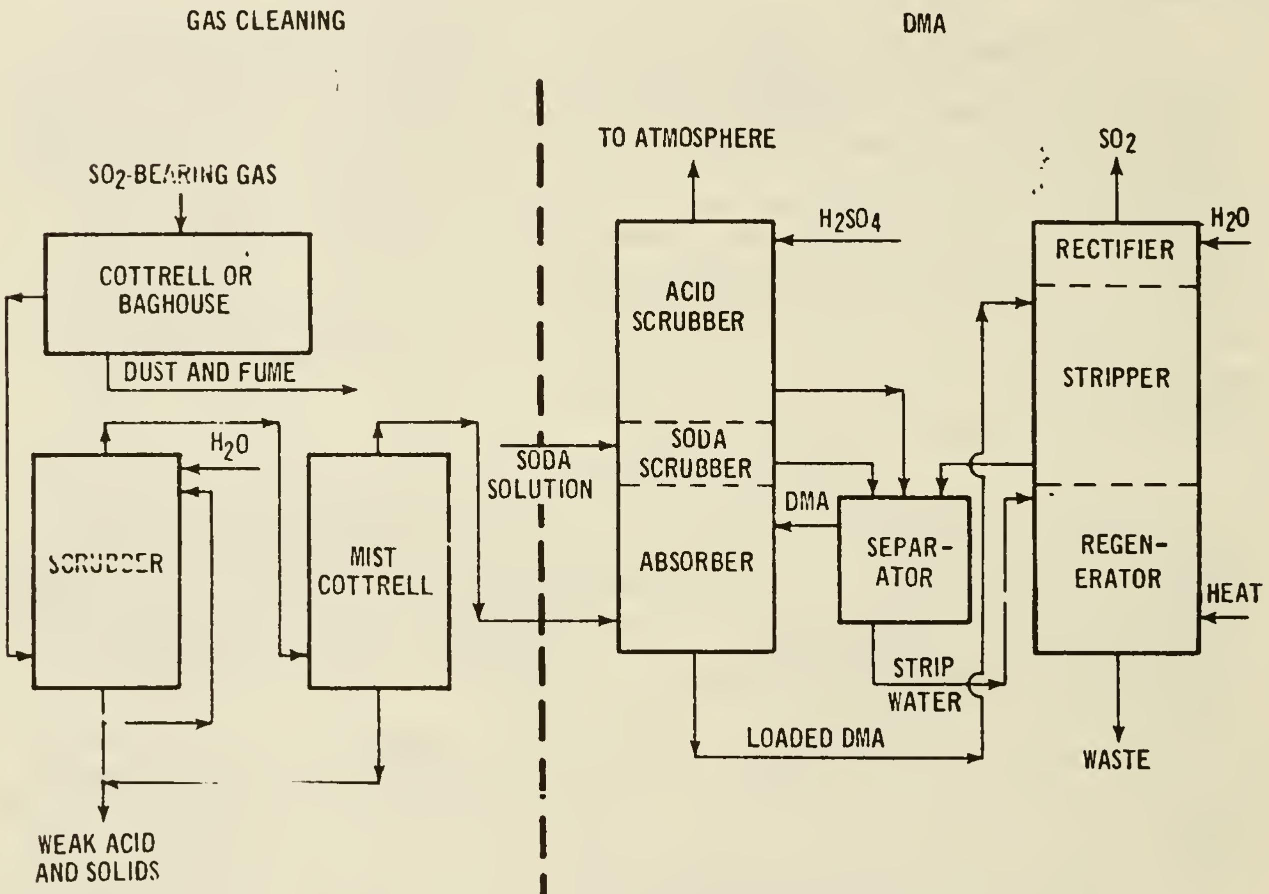


Figure 4-3 DMA Scrubbing Process.

"The hot sulfur dioxide is cooled, scrubbed again with cold water, and dried in a tower with 98 percent sulfuric acid. The gas is then compressed, cooled, liquified, and run to storage."

Survey of Operating Experience

"A partial list of commercial applications of ASARCO DMA sulfur dioxide absorption systems is shown in Table 4.3.

"The first domestic commercial application of the DMA absorption system was made by ASARCO in 1947 to recover sulfur dioxide from Dwight-Lloyd lead sintering machine off-gases. The lead smelter located at Selby, California is no longer in operation; however, the DMA absorption system is leased to a chemical company. The DMA plant was nominally rated at 20 tons of liquid SO_2 per day. The sulfur dioxide content of the inlet gases usually ranged from 4 to 6 percent and averaged approximately 5 percent. The sulfur dioxide concentration in the process off-gases ranged from a low of approximately 500 ppm in the winter months to as high as 3000 ppm in the summer months, depending primarily on cooling water temperature. Problems associated with materials of construction were encountered; however, these problems, in general, were satisfactorily resolved. Lead, as a material of construction, was extensively employed to eliminate corrosion.

"In 1949, the DMA process was first utilized by the Tennessee Copper Company (Now Cities Service Company) at their smelter operations at Copperhill, Tennessee. The capacity of the plant was nominally rated at 30 tons of liquid SO_2 per day. Subsequently, the capacity of the original plant was increased and a second DMA plant added. The two DMA plants are currently rated at 40 and 55 tons of liquid SO_2 per day, respectively. The feed stream for the DMA plant is 6 percent SO_2, and is a mixture of process off-gases from iron and copper roasters, copper reverberatory furnace and copper converters. The inlet gas to the DMA scrubber is precleaned in the same system as acid plant gas, then bled off before the acid plant absorber. The sulfur dioxide concentration of the off-gases from the DMA absorption tower approximates 3000-5000 ppm, but reportedly the absorption tower could be operated as low as 1500 ppm without requiring major modifications. The DMA plants were primarily designed to produce liquid SO_2 for market and were not built as air pollution control devices. The only operating difficulty associated with the DMA plants is that of regulating the pH of the system. If pH control is lost, carbonation occurs causing vaporization in the pumps."

4.3.3 Ammonia Scrubbing Systems

"Ammonia scrubbing systems have received considerable attention in the history of SO_2 removal from process off-gases. The reasons for this include relatively high affinity of ammonia solutions for SO_2 and the ability to keep all the compounds involved in solution, thereby avoiding scaling and silting problems in the scrubbers.

"The Cominco ammonia absorption process was developed by the Consolidated Mining And Smelting Company of Canada, Ltd. (Cominco) in 1936. The U.S. licensor for the process is Olin-Mathieson Chemical Corporation. Plant units have been built by Cominco in Trail, B.C., Canada to treat gases from lead and zinc smelting operations. The Olin-Mathieson Corporation has installed plants to treat the tail gases from sulfuric acid plants."

Table 4-3 ASARCO DMA installations.[5D]

	Company	Process	DMA Design Capacity Liquid SO_2	SO_2 Concentration		Remarks
				Inlet	Outlet	
1.	American Smelting and Refining Company Selby, California	Dwight-Lloyd lead sinter machine	20 T/D	4-6%	500-3000 ppm	Outlet concentration related to cooling water temperature. No longer operating on smelter off-gases.
2.	Cities Service Company Copperhill, Tennessee	Mixture of gases from iron and copper roasters, reverberatory furnaces and converters.	#1 40 T/D #2 55 T/D	$\geq$6%	2000 ppm	Two DMA units in operation.
3.	Phelps Dodge Corporation Ajo, Arizona	Copper smelter reverberatory furnace and/or converters	150 T/D	1 1/2-2%		Plant in start-u phase.
4.	American Smelting and Refining Company Tacoma, Washington	Copper converters	200 T/D	3-10%		Plant under construction.

Summary

The Cominco absorption process has been used to treat process off-gases with sulfur dioxide concentrations as low as 0.5 percent, with very good recovery. Tail gases contain as little as 0.03 percent sulfur dioxide

"The process has been utilized to recover sulfur dioxide included in process off-gases from Dwight-Lloyd lead sintering machines, zinc roasters, and sulfuric acid plant tail gases.

"It is concluded that the Cominco process is a viable process that can be utilized to control sulfur dioxide emissions from properly cleaned and conditioned smelter process off-gases that have sulfur dioxide concentrations in the range of 0.5 to 6.0 percent."

Process Description

A simplified description of the Cominco process is as follows (see Figure 4-4). Hot smelter off-gas is treated and conditioned prior to introduction into the first scrubbing tower. The gases are cooled, fine solids are washed out, and sulfur trioxide is absorbed to form weak sulfuric acid. The cooled off-gases then pass to the bottom of a scrubbing tower where they are contacted with a counter current flow of ammonium sulfite-bisulfite solution. The solution in the first scrubber is maintained at low pH (approximately 4.6) and high salt concentration. Sulfur dioxide is absorbed to form additional ammonium bisulfite. A portion of the solution is recycled back through the tower, and a portion of the solution from the tower is sent to the stripper.

"The partially cleaned gases then pass to a second scrubber where additional sulfur dioxide is removed by contact with an ammonium sulfite-bisulfite solution that is at a high pH (approximately 5.4) and has a low salt concentration. A portion of the scrubbing solution is recycled through the scrubber, and a portion of the solution from the tower is sent to the scrubber. The off-gas from the scrubber passes to the atmosphere.

"The bisulfite solution diverted to the stripper is acidified with sulfuric acid and stripped with air to produce about a 25 percent sulfur dioxide gas stream, and a solution of ammonium sulfate containing about 10 percent of the feed sulfur. The ammonium sulfate is then crystallized out and utilized as a fertilizer.

'If the consumption of sulfuric acid and ammonia, and the production of ammonium sulfate are not economically favorable, the sulfur dioxide can be removed from the ammonium bisulfite solution by stripping with steam. Under the name of the "exorption process," this type of system was used by Cominco during the years 1940 to 1943 permitting the recycle of 30 percent of the required ammonia. It is still considered by Cominco to be a feasible process for use under appropriate economic conditions."

Survey of Operating Experience

"A partial list of commercial applications of Cominco type ammonia scrubber systems is shown in Table 4-4."

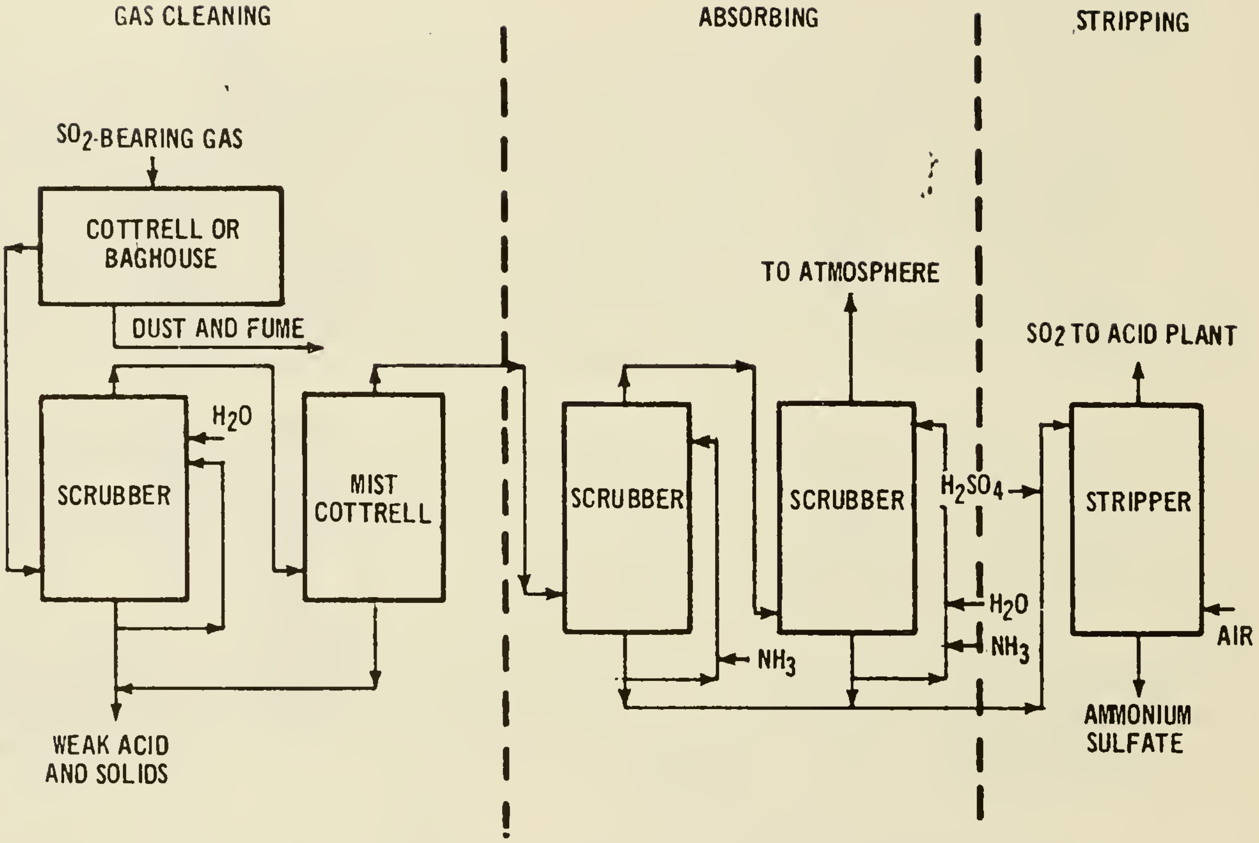


Figure 4-4 Cominco ammonia scrubbing process.

Table 4-4 COMINCO TYPE AMMONIA SCRUBBER INSTALLATIONS

	Company	Process	Volume	SO_2 Concentration Inlet	 Outlet	Remarks
1.	Consolidated Mining and Smelting Company of Canada, Ltd. Trail, B.C., Canada[7A]	Lead sintering	200,000 SCFM	15,000 - 25,000 ppm	1200 ppm	
		Zinc flash and multihearth roasters	0-45,000 SCFM	60,000 ppm	1000 ppm	Handles excess not sent to acid plant
		Sulfuric acid plant tail gases	50,000-95,000 SCFM	5000 ppm	700 ppm	
2.	Allied Chemical Corp. Newell, Pennsylvania[6A]	Sulfuric acid plant tail gases	-	3000 ppm	100 ppm	Ammonium salt solution incinerated in pyrite roaster system
3.	Olin Chemical Corp. Beaumont, Texas[4A]	Sulfuric acid plant tail gases	-	3000 ppm	750 ppm	
		Sulfur recovery plant tail gases	-	20,000 ppm	2000 ppm	

4.3.4 Sodium Sulfite-Bisulfite Scrubbing

Most of the development work on a sodium sulfite-bisulfite scrubbing system in this country has been conducted by Davy Power Gas (formerly Wellman-Lord). Davy began this development about the mid-1960's using the potassium rather than the sodium salt. One of the primary reasons given for discontinuing the use of potassium was that numerous pilot plant investigations had determined that regeneration costs were unduly high.

"A series of pilot plant tests were run prior to the first commercial installation of this process. These pilot plants ranged in size from about 600 to 50,000 scfm and were installed on a variety of sources which included coal and oil-fired steam generators and smelter processes such as converters and reverberatory furnaces."

Summary

"There are no known commercial sodium sulfite-bisulfite scrubbing systems installed to minimize sulfur dioxide emissions from either domestic or foreign primary copper, lead or zinc smelters; however, a number of domestic and foreign installations have been made to control tail gas emissions from sulfur recovery plants, sulfuric acid plants and oil-fired steam generators. The sulfur dioxide concentration in the process off-gases ranged from 2100 ppm to 13,000 ppm. The sulfur dioxide concentration in the Wellman-Lord absorber off-gases was 500 ppm or less.

"It is concluded that sodium sulfite-bisulfite absorption systems appear to be technically feasible to minimize sulfur dioxide emissions from either domestic or foreign primary copper, lead or zinc smelters; however, a number of domestic and foreign installations have been made to control smelter off-gases without excessive oxidation of the absorbent resulting in a required large purge stream and, consequently, high costs. Both Davy Power Gas and Japanese organizations are working hard to improve this disadvantage."

Process Description

"The Davy Power Gas scrubbing process is of the cyclic-regenerative type. Concentrated sulfur dioxide is recovered as a valuable product and the sodium sulfite-bisulfite absorbent is thermally regenerated and recycled through the system.

"A simplified flow diagram for the Davy Power Gas scrubbing system is depicted in Figure 4-5.

"As with most cyclic-regenerative absorption systems, pretreatment of the process off-gases is required if it is necessary to cool the process off-gases and to remove particulates and acid gases that may interfere with the absorption process or cause problems such as corrosion and plugging or fouling of the system. This pretreatment step must be studied on a case-by-case basis to insure the selection of the optimum design in relation to the overall facility.

"The process description is essentially as follows. Pretreated SO_2 laden process off-gases are introduced into a scrubber where they are absorbed in a counter-current flow of a solution of sodium sulfite-bisulfite. The rich

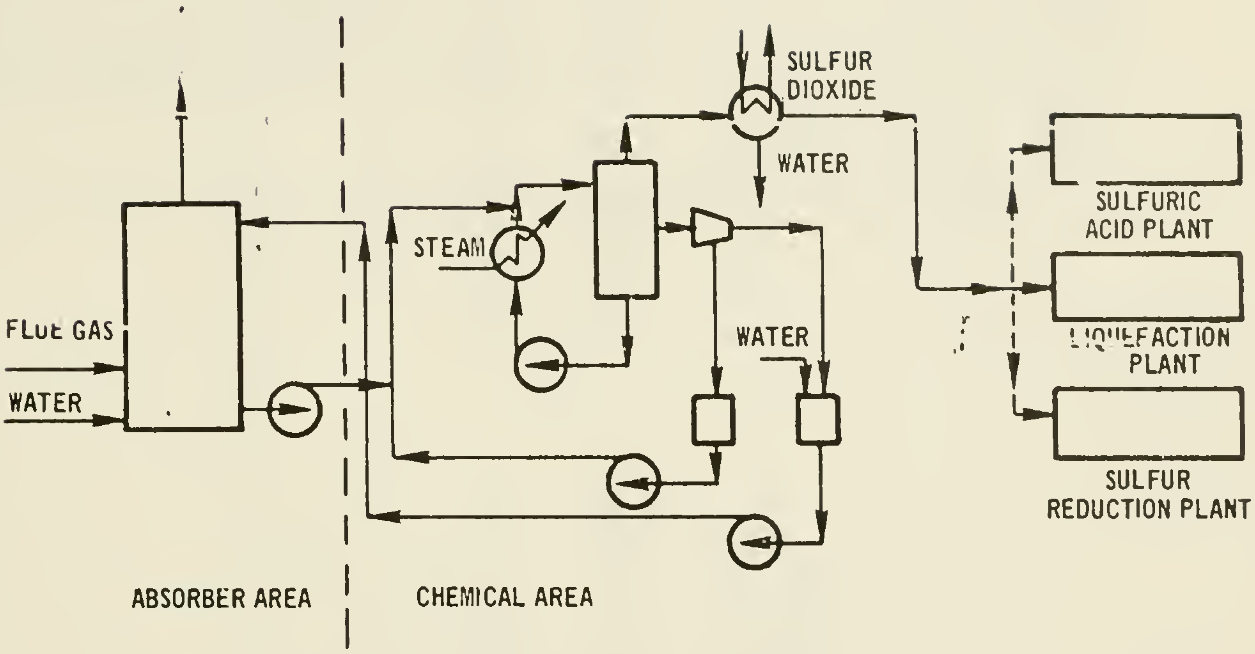


Figure 4-5 Davy Power Gas scrubbing process.

absorbent from the bottom of the scrubber is pumped to an evaporator crystallizer system where it is heated by indirect heat exchange with low pressure steam. As a result of the regeneration step, steam and SO_2 are driven off; and sodium sulfite crystals are formed in the liquid. The wet sulfur dioxide gases are run through a condenser where the bulk of the steam is removed. The concentrated SO_2 stream can be utilized in a sulfuric acid plant, a sulfur recovery plant, or some other appropriate sulfur dioxide process scheme.

"The liquid phase from the evaporator crystallizer is sent to a centrifugal separator where the crystals of sodium sulfite are removed. These crystals are added to the water that was condensed from the SO_2 stream and the solution thus formed is recycled to the scrubber. The clarified liquor from the centrifugal separator is recirculated to the evaporator. A portion of the clarified liquor is purged from the system in order to prevent a build-up of sodium sulfate in the system. The amount of sodium sulfate in the feed to the scrubber is controlled at about 5 percent by weight.

"A partial list of commercial applications of the Davy Power Gas sulfur dioxide absorption system is shown in table 4-5."

Table 4-5 DAVY POWER GAS INSTALLATIONS (Survey of Operating Experience)

	Company	Process	Volume	SO_2 Concentration Inlet	 Outlet
1.	Olin Corporation Paulsboro, New Jersey$_{2W}$	Sulfuric acid plant tail gases	45,000 SCFM	4500 ppm	<500 ppm
2.	Japan Synthetic Rubber, Ichihara City, Chiba, Japan$_{2W}$	Two oil-fired boilers	124,000 SCFM	2100 ppm	<200 ppm
3.	Toa Nenryo Kogyo, Ltd. Kawasaki, Kanagawa, Japan$_{2W}$	Sulfur recovery plant tail gas	41,000 SCFM	13,000 ppm	200 ppm
4.	Standard Oil Company of California, El Segundo, California$_{5W}$	Three sulfur recovery plant tail gases	75,000 ACFM		500 ppm

Appraisal of Operating Problems Peculiar to Treatment of Smelter Effluents

"The advantage of the Davy Power Gas scrubbing system is the simplicity of its unit operating and the avoidance of steam stripping of the absorbent, thus substantially reducing steam requirements.

"It is recommended that the process off-gas be as free as possible from dust, fume, and vapor or gaseous contaminants such as arsenic trioxide, hydrogen chloride, hydrogen fluoride and sulfur trioxide. Solid particles in the absorbent solution may produce mechanical problems such as plugging or erosion while acidic gases and vapors will consume absorbent or cause chemical problems such as corrosion.

"Smelter effluents in many cases could also cause problems with the system due to the presence of high concentrations of oxygen in the process off-gas and the possibility of introducing potential oxidation catalysts into the absorbent. In both cases a build-up of an excessive sodium sulfate concentration in the absorbent could result.

"In the required purging of sodium sulfate from the absorption system, a portion of the sulfur dioxide is lost because of purging of associated sodium sulfite and sodium bisulfite. Total sodium sulfate formation directly effects the quantity of make sodium hydrogen required.

E. Control Costs

Appendix C contains excerpts from a document entitled "Background Information - Proposed New Source Performance Standards for Primary Copper, Zinc and Lead Smelters" (4). This document, published in draft form in August, 1973, discusses economics associated with air pollution control from the copper industry.

New Source Performance Standards, authorized under Section 111 of the Federal Clean Air Act of 1970 means "a standard for emissions of air pollutants which reflects the degree of emission limitation achievable through the application of the best system of emission reduction which (taking into account the cost of achieving such reduction) the Administrator determines has been adequately demonstrated."

The costs in the EPA document were developed for "new town-site smelters." Table 6-11 of Reference 4 shows the capital cost of $8.84 million for a 660 ton per day dual stage acid plant (80,000 SCFM gas flow). This cost does not include auxiliary facilities such as power lines necessary to make an operable unit. It does include neutralization requirements and assumes free unlimited limestone available. In its June, 1973, application for authority to construct, the Anaconda Company reported costs of about $11 million for modifications to the smelter which included the 660 ton per day sulfuric acid plant, water cooled converter hoods, converter uptakes and flues, gas scrubber, glass fiber flue to acid plant, acid storage facilities, and loadout facilities. Therefore, it appears that the EPA costs for new plants are also reasonable for existing facilities for this size of acid plant.

Another dual stage acid plant with an acid capacity of about 900 tons per day would be required for eventually achieving 90% control of present smelter sulfur oxide emissions. According to Table 6-12, Case 1B, Reference 4, the capital cost of a plant this size would be about $11.4 million. An associated neutralization facility would add $5.5 million. The operating costs from Table 6-12 are $5.2 million per year. The above cost figures were taken from the electric smelting configuration. The current green feed reverberatory smelting configuration at Anaconda appears to be only temporary. The higher control costs for the electric smelting configuration result from the larger plant necessary to process off-gases from both the smelting furnace and converters rather than just the converters.

Such controls would cost approximately 2.5-3.0 cents per pound of copper produced.

III. EXISTING AMBIENT ENVIRONMENT

A. Air Quality

A comprehensive study of air pollution in the Deer Lodge Valley was conducted from August, 1965, through June, 1966 (13). This study was conducted by the Air Quality Bureau, Montana State Department of Health and Environmental Sciences, with partial support from the U. S. Department of Health, Education and Welfare. Sampling included over 2,640 aerometric measurements and sixty sulfur dioxide samples using the lead peroxide candle method. This report states: "Levels of sulfur dioxide were excessive in the Anaconda area but dropped off rapidly in all directions from Anaconda."

The geography of the Deer Lodge Valley, with the town of Anaconda at the south end, is quite conducive to meteorological inversions. The valley is about 35 miles long, about 10 miles wide and surrounded on all four sides by high mountains. The elevation at the south end of the valley is about 5,000 feet and is about 4,500 feet at the north end (Garrison) (13).

Surface winds as recorded by the state in valley floor locations near Anaconda are predominantly westerly through southerly with predominant speed range of 3.5 to 30 mph. Winds at stack height are mainly from the southwest in fall and winter periods. Spring and summer seasons bring prevailing winds along the southwest-northeast axis with noticeable components from all other directions. Wind speeds up to 100 miles per hour have been recorded at stack height.

The average annual inversion frequency is probably close to 40% of the time. It is highest in the winter at about 45-50% and lowest in the spring at about 30% of the time. These frequencies are among the highest in the nation. Because of geographic and weather factors, the Deer Lodge valley has a high potential for air pollution problems (13).

Sulfur dioxide concentrations in the air at or near Anaconda showed a 30% increase between 1961-1962 and 1965-66. Smelter production between these two test periods increased from 133,227 T./yr to 155,796 T./yr (14). The lead peroxide candle tests conducted in 1965-66 showed that Anaconda has a higher sulfur trioxide concentration than the other stations sampled, Deer Lodge, Galen, Opportunity, and Crackerville. The average results were:

Anaconda - 0.74 mg/SO_3/100 cm^2/day
Opportunity - 0.52 mg/SO_3/100 cm^2/day
Galen - 0.39 mg/SO_3/100 cm^2/day
Crackerville - 0.25 mg/SO_3/100 cm^2/day
Deer Lodge - 0.17 mg/SO_3/100 cm^2/day

Maximum results were:

Anaconda - 0.99 mg/SO_3/100 cm^2/day
Opportunity - 0.85 mg/SO_3/100 cm^2/day
Galen - 0.60 mg/SO_3/100 cm^2/day
Crackerville - 0.32 mg/SO_3/100 cm^2/day
Deer Lodge - 0.29 mg/SO_3/100 cm^2/day

The units given above are milligrams of sulfur trioxide formed per day in the candles with surface areas of 100 square centimeters.

Current state ambient air quality standards limit reactive sulfur (sulfation) to 0.25 mg/SO_3/100 cm^2/day maximum annual average and 0.50 mg/SO_3/100 cm^2/day maximum for any one month average. As can be seen above, if the current ambient air quality standards had been in effect at that time, both the monthly and annual limits would have been exceeded during the 1965-66 test periods.

Sulfation rate data from ambient air sampling in 1971, 1972, and 1973 are summarized in Table 2. The sampling locations are shown in Figure 3. Several facts are evident. Both the maximum monthly and annual averages were exceeded in 1971, 1972 and 1973. For some of the stations a trend over these three years is evident in that recorded concentrations are less in 1973. This substantial drop corresponds in time to the installation of the water cooled hoods on the converters and use of the 660 T./day sulfuric acid plant. First use of the new ducting began about January, 1973, and the sulfuric acid plant was started in June, 1973. Even though the acid plant was not started until June, 1973, the use of the new hoods and ducting eliminated almost all of the low level sulfur oxide emissions from the openings in the converter building. Approximately 95% emission control is possible using the new hoods.

TABLE 2

Number of Violations of State Ambient Air Quality Standards
Sulfation Rate Data

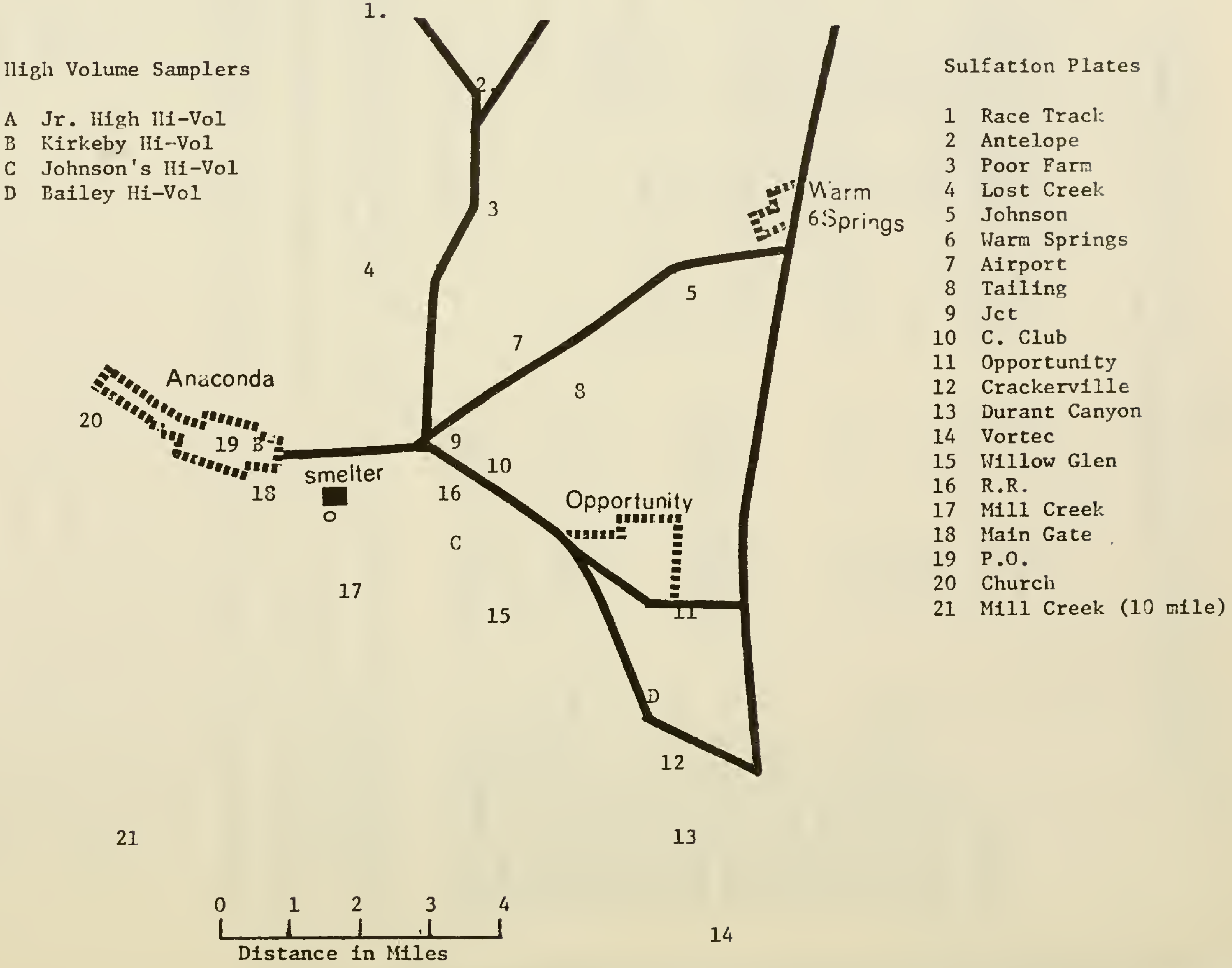
Stations	1971 0.50* Monthly Standard	1971 0.25# Annual Standard	1972 0.50 Monthly Standard	1972 0.25 Annual Standard	1973 0.50 Monthly Standard	1973 0.25 Annual Standard
Main Gate	6(.94)+	1(.63)		(.23)		
East Anaconda Jct.	7(4.80)	1(2.26)	4(4.80)	1(1.73)	4(1.10)	1(.52)
Lost Creek 1 Mile	5(.74)			1(.42)		
Sky Lodge Airport	8(1.90)	1(1.02)	4(2.80)	1(.87)	4(.65)	1(.38)
Johnson Ranch	3(.80)	1(.43)	2(.66)	1(.41)		
Poor Farm				1(.57)	3(1.03)	1(.46)
Tailings Pond						(.24)
Antelope Creek					1(.65)	1(.32)
Mill Creek RR	6(2.90)	1(1.43)	6(2.70)	1(1.09)	2(.69)	1(.26)
Country Club Rd	7(1.20)	1(.61)	5(1.20)	1(.62)		(.24)
Crackerville	6(1.30)	1(.73)				
One Way Sign Oppor.	2(.68)	1(.61)	1(.77)	1(.36)		(.21)
Durant Canyon			1(.53)	1(.42)	3(.59)	1(.34)
Vortex					2(.65)	1(.30)
Willow Glen					3(.75)	1(.40)
Mill Cr. 1.2 miles	4(.86)	1(.37)				
Mill Cr. 10 Miles	4(.87)	1(.38)				1(.27)
Post Office						1(.29)
Church of Christ	6(.92)	1(.54)				
Race Track Exit	7(1.10)	1(.64)				
Warm Springs	2(.70)	1(.33)		(.24)		(.23)

*0.50 milligrams sulfur trioxide per 100 square centimeters per day, maximum for any one-month period.

#0.25 milligrams sulfur trioxide per 100 square centimeters per day, maximum annual average.

+Numbers in parenthese indicate highest value recorded in same units as above.

Figure 3 Location of Sulfation Plates and Hi-Volume Samplers in the Anaconda Vicinity



High Volume Samplers

A	Jr. High Hi-Vol
B	Kirkeby Hi-Vol
C	Johnson's Hi-Vol
D	Bailey Hi-Vol

Sulfation Plates

1	Race Track
2	Antelope
3	Poor Farm
4	Lost Creek
5	Johnson
6	Warm Springs
7	Airport
8	Tailing
9	Jct
10	C. Club
11	Opportunity
12	Crackerville
13	Durant Canyon
14	Vortec
15	Willow Glen
16	R.R.
17	Mill Creek
18	Main Gate
19	P.O.
20	Church
21	Mill Creek (10 mile)

Sulfur dioxide sampling data for the Anaconda, Montana area from December, 1971 to November, 1973, is summarized in Table 3. Sampling locations are shown in Figure 4. It can be seen that violations of the Montana 1-hour and national primary and secondary standards occurred in 1971, 1972 and 1973 although the concentrations of sulfur dioxide appears to be less in 1973. Only the Poor Farm station has enough data for any kind of comparison of the violations in the three years. The major problem with most ambient sampling in the smelter area lies with the large difference between the elevation of the top of the stack and the valley floor where most sampling has been done. Most of the acceptable sampling sites at higher elevations around the smelter, where higher ground level concentrations of sulfur oxides are expected, have, until very recently, been inaccessable to the air sampling equipment.

It should also be noted that a substantial reduction in copper production has occurred in 1972 and 1973 (14). This reduction also accounts for decreased ambient readings.

Suspended particulate data, obtained with glass fiber high-volume filters is summarized in Table 4. Violations of both federal and state standards are shown.

TABLE 3

Number of Violations of Ambient Air Quality Standards, Coulometric Sulfur Dioxide Sampling

Location, Source,	71 72				73			
& Standard	D J F	M A M	J J A	S O N	D J F	M A M	J J A	S O N
Mill Creek (AC)								
1 hr^{e}			0^{a}	2(.56)	27(.57)^{b}			
3 hr			0^{a}	0	3(.64)^{b}			
.10			0^{a}	0	5(.17)^{b}			
.14			0^{a}	0	4(.17)^{b}			
Motel (AC)								
1 hr			1(.27)^{d}	8(.53)	15(.86)^{b}			
3 hr			0^{a}	0	1(.63)^{b}			
.10			0^{a}	1(.12)	4(.16)^{b}			
.14			0^{a}	0	2(.16)^{b}			
Post Office (EPA)								
1 hr					0^{c}	18(.90)	24(.55)^{d}	[illegible]
3 hr					[illegible]	2(.65)	0^{d}	0
.10					0^{c}	3(.12)	1(.10)^{d}	5(.29)
.14					0^{c}	0	0^{d}	4(.29)
Willow Glen (State)								
1 hr						6(.50)	8(.35)^{d}	1(.27)
3 hr						[illegible]	0^{d}	[illegible]
.10						1(.10)	[illegible](.11)^{d}	0
.14						0	0^{d}	0
Tailings Pond (EPA)								
1 hr						7(.40)	2(.23)	60(.45)
3 hr						0	0^{d}	0
.10						0	0^{d}	9(.24)
.14						0	0^{d}	[illegible](.24)
[illegible] ([illegible])								
1 hr						1(.66)	0^{d}	51(.75)
3 hr						0	0^{d}	3(.62)
.10						0	0^{d}	3(.44)
.14						0	0^{d}	3(.44)

TABLE 3 (Cont.)

Location, Source,	71 72				73			
& Standard	D J F	M A M	J J A	S O N	D J F	M A M	J J A	S O N
Poor Farm (State)								
1 hr^{e}	33(.70)	1(.28)	0	3(.32)	15(.53)^{b}			
3 hr	0	0	0	0	0^{b}			
.10	2(.35)	0	0	0	2(.17)^{b}			
.14	1(.35)	0	0	0	1(.17)^{b}			
Antelope Creek (St)								
1 hr^{e}					0^{c}	4(.42)	0^{d}	
3 hr					0^{c}	0	0^{d}	
.10					0^{c}	0	0^{d}	
.14					0^{c}	0	0^{d}	
Airport (AC)								
1 hr			0^{a}	0	10(.75)^{b}			
3 hr			0^{a}	0	0^{b}			
.10			0^{a}	0	1(.11)^{b}			
.14			0^{a}	0	0^{b}			
Warm Springs (st)								
1 hr	0							
3 hr	0							
.10	0							
.14	0							
Opportunity (ACM)								
1 hr			0	0	4(.81)^{b}			
3 hr			0	0	0^{b}			
.10			0	0	0^{b}			
.14			0	0	0^{b}			
Opportunity (EPA)								
1 hr			0	0				
3 hr			0	0				
.10			0	0				
.14			0	0				

TABLE 3 (Cont.)

Location, Source.	71 72				73			
& Standard	D J F	M A M	J J A	S O N	D J F	M A M	J J A	S O N
Kucera(State)								
1 hr[e]				0	2(.39)	19(.42)	4(.45)[d]	
3 hr				0	0	0	0[d]	
.10				0	0	0	0[d]	
.14				0	0	0	0[d]	
Weather Hill (AC)								
1 hr				0	13(.60)[b]			
3 hr				0	0[b]			
.10				0	1(.11)[b]			
.14				0	0[b]			

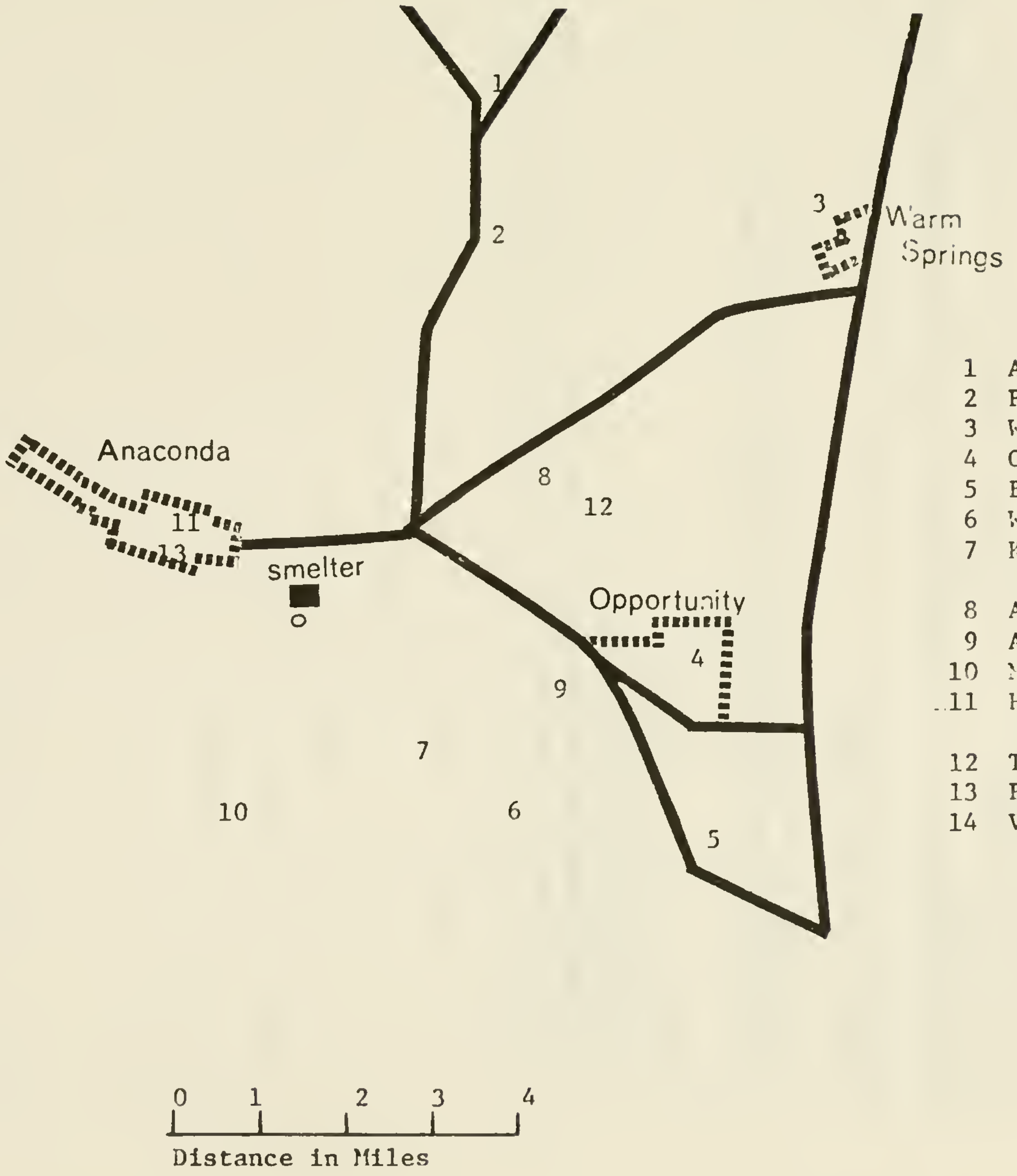
[a] Aug. data only
[b] Dec. & Jan. data only

[c] Feb. data only
[d] June & July data only

[e] Air Quality Standards for Ambient Sulfur Dioxide

Montana Standard	
1 hour	0.25 ppm not to be exceeded for more than one hour in any 4 consecutive days
National Standards	
3 hour standard (sec.)	0.5 ppm maximum 3 hour conc. not to be exceeded more than once a year
24 hour std. (primary)	0.14 ppm max. 24 hour conc. not to be exceeded more than once a year
(secondary)	0.10 ppm max. 24 hour conc. not to be exceeded more than once a year. (This standard is to be used as a guide in assessing implementation plans to achieve the annual standard.)
Annual (primary)	0.03 ppm annual arith. mean.

Figure 4 Continuous Monitoring for SO_2



1	Antelope	(state)
2	Poor Farm	"
3	Warm Springs	"
4	Opportunity	"
5	Bailey	"
6	Willow Glen	"
7	Kucera	"
8	Airport	(Anaconda smelter)
9	Anaconda Company	"
10	Mill Creek	"
11	Hotel	"
12	Tailings Pond	(EPA)
13	Post Office	"
14	Vortec	"

TABLE 4

TOTAL SUSPENDED PARTICULATE LEVELS IN ANACONDA AREA
RUNNING YEAR VALUES

	Johnson Res. Mill Creek	Kirkeby Res. Anaconda	Jr. High Anaconda	Bailey Res. SE of Anaconda
Geometric Mean (ug/M^3)	49	28	46	36
Arithmetic Mean (ug/M^3)	59	36	54	44
Max. 24 hour Ave. (ug/M^3)	235	208	249	93
No. days over 150 ug/M^3	1	1	1	0
No. days over 200 ug/M^3	1	1	1	0
No. days data	31	99	100	7
Sampling period	Mar-Nov 1971	Apr 72-June 73	Feb 71-Mar 72	Oct-Nov 1971

Applicable State Standards

75 ug/M^3 (microgram per cubic meter) annual geometric mean
200 ug/M^3 not to be exceeded more than 1% of days a year

Applicable Federal Standards

75 ug/M^3 annual geometric mean
150 ug/M^3 max. 24 hour conc. not to be exceeded more than once a year (secondary)
200 ug/M^3 max. 24 hour conc. not to be exceeded more than once a year (primary)

B. Vegetation Damage

The Anaconda copper smelter in Anaconda, Montana is located at the southwestern edge of the Deer Lodge Valley. Elevation in the valley range from 5000-5400 feet with the lowest levels along the Clark Fork River. The mountains at the edge of the valley reach elevations of 7,000 to 9,000 feet.

The Anaconda Company smelter stands on a hill some 400 feet above the valley floor. The stack of the smelter is nearly 600 feet high so that smoke from the smelter is discharged at an elevation of approximately 6400 feet.

Wind direction is predominantly from the South except in the spring when it comes from the Northwest. The precipitation averages 15 to 20 inches per year, resulting in semi-arid conditions.

Average summer temperatures are about 65°F. while average winter temperatures are about 25°F. The climate can be classified as continental.

Little timber is found in the valley except along stream and river banks. The higher mountainous areas sustain thick coniferous forests. The valley tree communities occurring along water systems are predominated by willows, aspens, and cottonwoods. The coniferous forests are comprised of Douglas Fir, Engelmann Spruce, Lodgepole Pine, Limber Pine, Rocky Mountain Juniper, and Common Juniper (15).

Sulfur dioxide (SO_2), which damages vegetation, is produced in the smelting of copper sulfide ores. Although strict emission levels have been set for SO_2, violations still occur during periods of adverse meteorological conditions such as inversions or air stagnation. Unfortunately the Montana state tree, Ponderosa Pine, is particularly sensitive to it (16).

It is not the SO_2 molecule as such which causes injury to plant tissue. Following absorption into the plant, this compound is oxidized to form the sulfite ion SO_3. This sulfite ion is extremely toxic to the plant, probably due to its reducing property (17) and is responsible for visible damage. Further oxidation of the sulfite to sulfate by the plant reduces the toxicity by approximately thirty times (18).

Sulfur dioxide damage is characterized as chronic or acute depending on the length and concentration of the exposure. Chronic symptoms which result from long term exposure at low levels appear as yellowing (or chlorosis) of the affected tissue. Acute SO_2 damage which occurs from short term exposure at higher levels results in areas of dead tissue (necrosis). A plant exposed to both high and low levels of SO_2 may exhibit both chronic and acute damage symptoms. These symptoms usually appear in the interveinal areas of leaves and on the tips of conifer needles. With conifers, distinct banding may appear (19). Premature shedding of needles is also typical of SO_2 damage to conifers. The needles of trees in the Anaconda vicinity exhibit both chlorotic mottle and tip necrosis, an indication of both chronic and acute exposure. The damage appears typically on mature tissue. The presence of interveinal necrosis on cherry trees in the same vicinity further indicate SO_2 damage.

Scientists have documented the levels of SO_2 and exposure times which characteristically result in damage to vegetation. The U. S. Department of Health, Education and Welfare, Public Health Service (1967) has made a determination of the effect of SO_2 exposure and concentration on vegetation. Their findings are included in Figure 5. Note from this graph that acute damage symptoms result when the SO_2 level reaches 0.5 ppm for 6 hours or 0.80 ppm for one hour.

By comparing these federally determined toxic levels with data of the Air Quality Bureau, it becomes immediately clear that levels of SO_2 hazardous to sensitive plants are present in the vicinity of the Anaconda copper smelter (table 5). For example, the SO_2 levels of 0.60-0.65 ppm/2 hours which were monitored at the Anaconda Post Office site on May 11, 1973, would be sufficient to cause visible damage to sensitive plants. Since levels as high as 0.90 ppm occurred during the period of May 11-14 at this site, the probability of damage to vegetation is augmented (20).

A study of precipitation chemistry of rain water falling within a 40-mile radius around The Anaconda Company smelter is now in progress. An associated study of the short-long needle syndrome of coniferous foliage in the Anaconda, Montana, area is also in progress (30).

The following figure summarizes the effects of sulfur oxides on vegetation very well. It was reproduced from publication no. 1619, "Air Quality Criteria for Sulfur Oxides," prepared by the U. S. Department of Health, Education, and Welfare, Public Health Service, in March, 1967 (21).

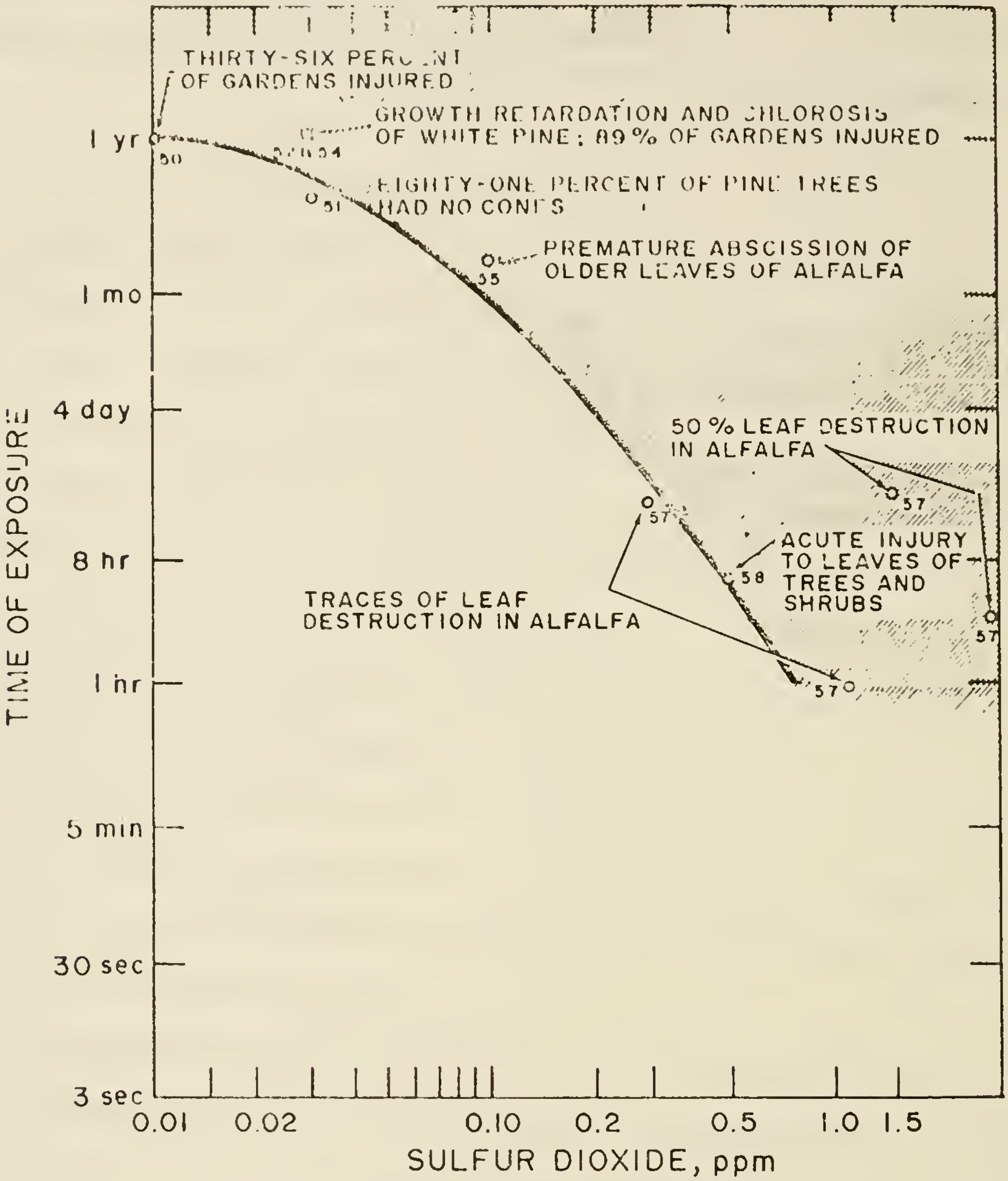


Figure 5 Effects of sulfur oxides pollution on vegetation.

▨ Range of concentrations and exposure times in which injury to vegetation has been reported.

☐ Range of concentrations and exposure times of undetermined significance to vegetation.

TABLE 5

EPA Coulometric SO_2 Measurements for May, 1973

Anaconda Smelter

Table of Sites where SO_2 levels were sufficiently high enough to cause damage to sensitive plants.

One Hour

Date	Site	SO_2 Range	Time
5/11/73	Post Office	0.60 - 0.65 ppm	10:00 a.m. - 12:00
5/13/73	Post Office	0.30 - 0.90 ppm	10:00 a.m. - 2:00 p.m.
5/14/73	Post Office	0.55 - 0.68 ppm	12:00 - 3:00 p.m.

3 Hour Running Average

Date	Site	SO_2 Peak-3 Hr. Ave.	Time
5/11/73	Post Office	0.48 ppm	10:00 a.m.
5/13/73	Post Office	0.65 ppm	10:00 a.m.
5/14/73	Post Office	0.62 ppm	12:00 noon

C. Human Health

The major health effect from sulfur oxides is irritation of the respiratory tract (22). The association is quite firm for the short-term air pollution episodes, but the long-term association must be considered probable. Sulfur dioxide is relatively soluble in water and can be absorbed in the mucus of the upper airways. Coughing is caused by sulfur dioxide and particulate matter in air and high levels of this combination has also been found to increase the frequency of colds and other acute upper respiratory infections (21). Sulfur dioxide has also been associated with allergic reactions in persons suffering from asthma (23). Increased airway resistance has been observed but appears to be minor in normal individuals (22). Persons suffering from chronic pulmonary disease or cardiac disorders or very young or old individuals, are affected the most (23). Increased death rates have been recorded following periods of high concentrations of sulfur dioxide and particulate in the ambient air (22). Sulfates, caused by the oxidation of sulfites and sulfur dioxide, appear to be a more harmful air pollutant than sulfur dioxide (24).

Some of the conclusions of the U. S. Department of Health, Education and Welfare, Public Health Service, published in 1969 (22) are that:

1. Sulfur dioxide concentrations of about 0.19 ppm (24-hour mean) with low particulate levels may increase the mortality rate.

2. Sulfur dioxide concentrations of about 0.11 to 0.19 ppm (24-hour mean) with low particulate levels may cause increased hospital admissions of older persons with respiratory problems and increased absenteeism.

3. Sulfur dioxide concentrations of about 0.21 ppm (24-hour mean) with particulate concentrations of about 300 ug/m^3 may cause accentuation of symptoms of chronic lung disease.

4. Sulfur dioxide concentrations of 0.037 to 0.092 ppm (annual mean) with particulate concentrations of about 185 ug/m^3 may increase the frequency of respiratory symptoms and lung disease.

5. Sulfur dioxide concentrations of about 0.040 ppm (annual mean) accompanied by a particulate concentration of 160 ug/m^3 may cause an increase in mortality from bronchitis and lung cancer.

The British study (item 5 above) has found an association between mortality from bronchitis and lung cancer and levels of air pollution (22). However, it cannot be positively stated that sulfur oxides are responsible constituents of the pollution.

The above information was recently confirmed by EPA (24) through continuing efforts to establish a more sound basis for federal ambient air quality standards. The results of this work are summarized in Tables 6 through 8. Table 8 shows that almost every person in this country living in an urban location is affected by sulfur oxide air pollutants.

EPA has studied the relationship between respiratory disease and exposure to smelter emissions in Northwest communities in 1971 (25,26). The results of the studies generally were that chronic bronchitis prevalence and relative severity in non-occupationally exposed adult residents of two high exposure Rocky Mountain smelter communities (Anaconda, Montana and Kellogg, Idaho) significantly exceeded morbidity rates found in residents of communities subjected to lower exposures. Occupational exposure further increased observed bronchitis morbidity. Excess bronchitis occurred with 2 to 3-year exposure to SO_2 concentrations of 109 to 186 ug/m^3 (0.0382 to 0.0651 ppm) and suspended sulfate concentrations of 8.6 to 20.4 ug/m^3 in the presence of low total suspended particulates. Metallic sulfates may well have accounted for the findings of excess bronchitis (25).

> "Acute respiratory morbidity in asthmatic children began to increase with exposures to low annual average levels of sulfur dioxide (46 ug/m3) (equivalent to 0.017 ppm) when moderately elevated levels of total suspended particulates (94-110 ug/m^3) were present. Unmistakably significant excesses in acute lower respiratory illnesses, especially croup, appeared among asthmatic and non-asthmatic children exposed to higher pollution levels for 3 or more years. Such levels involved annual average sulfur dioxide levels of 109 ug/m^3 (0.041 ppm) accompanied by low annual average levels of particulates (43 ug/m^3) and minimally elevated annual average levels of suspended sulfates (8.6 ug/m^3). There was also suggestive evidence that more serious infections including pneumonia that might require hospitalization tended to be more frequent in children exposed to these elevated pollution levels"(26).

TABLE 6

Best Judgment Threshold Estimates for Health Effects of Sulfur Oxides (24)

Adverse Health Effect	Best Judgment Threshold Estimate		
	Concentration ug/m^3		Averaging Time
	SO_2 (+)	SS(*)	
1. Aggravation of cardio-respiratory symptoms or lung symptoms in elderly patients with related illness	365(1.28)	10	24-hour average
2. Increased mortality	350(1.23)	NA	24-hour average
3. Aggravation of asthma	200 (0.700)	8-10	24-hour average
4. Reduced lung function	230(0.805)	11	annual mean
5. Increased frequency or severity of lower respiratory illness	91(0.032)	9	annual mean
6. Increased prevalence of chronic bronchitis	95(0.033)	14	annual mean

(+ Parts per million SO_2)

(* Suspended Sulfates)

TABLE 7

Safety Margin Included in Sulfur Oxide Standard (24)

Adverse Effect	Threshold Concentration ug/m^3 (+)	Primary Standard ug/m^3	Safety* Margin %
1. Aggravation of heart or respiratory symptoms in elderly	365(1.28)	365	0
2. Increased mortality	350(1.23)	365	0
3. Aggravation of asthma	200(0.700)	365	0 (-45)
4. Reduced lung function	230(0.805)	80	187
5. Increased lower respiratory illness	91(0.032)	80	14
6. Increased chronic bronchitis	95(0.033)	80	19

(+ Parts per million)

$$\text{*Safety margin} = \frac{\text{Threshold Concentration} - \text{Standard}}{\text{Standard}} \times 100$$

TABLE 8

Size of Population at Potential Risk of Pollutant-Induced Effect (24)

Adverse Effect	Expected Frequency of Adverse Effect in the Population (Rate per 100)	Potential Size* of Population at Risk
Chronic bronchitis	10% of adult population	8,400,000
Asthma	3%	4,200,000
Chronic heart illness	5% of adult population	4,200,000
Susceptible to respiratory infection	100	140,000,000

*Assumes a U.S. population of 200,000,000 and 70% of total population living in urban areas of increased pollution.

The concentrations of sulfur dioxide, particulates, and suspended sulfates given above are based on emissions estimates and dispersion models calibrated to observed air quality measurements made in the towns involved in this study.

Average sulfur dioxide levels around Anaconda as measured with State Department of Health and Environmental Sciences instruments gave the following results:

Poor Farm, 1971-72 = 0.009 ppm

Antelope Creek, 5 months, 1973 = 0.006 ppm

Willow Glen, 5 months, 1973 = 0.01 ppm

Bailey's Residence, 2 months, 1971 = 0.017 ppm

Kucera's Residence, 8 months, 1973 = 0.01 ppm

Anaconda Company data for 1972-73 showed the following sulfur dioxide concentrations in the ambient air:

Mill Creek, 6 months = 0.014 ppm

Marcus Daly Hotel, 6 months = 0.021 ppm

Anaconda Airport, 6 months = 0.013 ppm

Opportunity, 6 months = 0.007 ppm

Weather Hill, 3 months = 0.01 ppm

The sampling locations are shown in Figure 4.

Of the 10 sets of company or state sulfur dioxide data, only two locations had levels equal to or exceeding the 0.017 ppm sulfur dioxide level derived from the calibrated dispersion models. These were at the Bailey residence and the Marcus Daly Hotel. The Mill Creek and Anaconda Airport sampling stations had levels approaching this value.

D. Visibility

Suspended particles in the air reduce visibility by scattering and absorbing light. In urban air about 5 to 20% of the total particulate matter normally consists of sulfuric acid or sulfates (22) which are normally produced from sulfur dioxide within an hour or two after being released to the atmosphere. At Anaconda, this percentage is about 4.

About 80% of the sulfuric acid and sulfates are usually below 1 microns in diameter. This particle size is within the range of 0.1 to 1.0 microns in diameter. This range has the greatest adverse effect on visibility (22).

No visibility measurements in the ambient air near Anaconda have been made. Available literature gives an estimate of the local visibility reduction due to sulfur compounds.

". . . the likely effect of sulfuric acid and sulfate salts on visual range can be estimated from existing data on particle size distribution, refractive indices, and concentrations. Because of changes in particle size, at a given concentration of sulfuric acid mist or sulfate salts, visual range is affected more and more as relative humidity increases"(22). It is also true that if only sulfuric acid mist were involved at 50% relative humidity the estimated visual range would be about 100 miles at a concentration of 10 ug/m^3 but only about 1 mile at a concentration of 1,000 ug/m^3; at 98 percent relative humidity, the estimated visual ranges at the same concentrations would be respectively 10.0 miles and 0.10 mile. With a normally associated amount of sulfuric acid mist and other particulate matter present, the estimated visual ranges at 50 percent relative humidity would be about 50.0 miles and 0.5 mile at measured sulfur dioxide concentrations 0.01 and 1 ppm respectively; at 90 percent relative humidity the estimated visual ranges at the same concentrations would be about 15 miles and 0.2 mile respectively (21).

Different engineering units for sulfates and sulfur oxides have been used above. The units used for sulfur oxides (ppm) may be changed to the same units used for sulfates (ug/m^3) by multiplying ppm by 2860.

E. Economics

The Anaconda Company to date has refused to supply the Department with information on the costs of the smelter operation per pound of anode copper produced (2). A feasibility study prepared for the Company by Arthur G. McKee and Company has been withheld from the Department by The Anaconda Company (1).

For the entire company reported total net earnings in 1972 were slightly over $133 million. This included extraordinary income of almost $89 million due to the sale of the Forest Products Division. That actual sale price was $117 million with some proceeds being applied to the reduction of long-term indebtedness and to increase working capital, thus strengthening the company's overall financial position. Earnings for 1973 were up 58% to $69.7 million. Working capital at the end of 1972 was $291 million. In 1971, the company reported a total loss of $353.8 million largely resulting from the expropriation of its investments in Chile (27). The present Chilean government recently appointed a representative to negotiate with company officials regarding compensation for the losses.

In 1972, The Anaconda Company, Primary Metals Division, produced 176,469 tons of copper at the Anaconda smelter (352.94 million pounds). Sales were three hundred fifty-nine million, nine hundred fifty thousand dollars (27). In 1973, the Anaconda smelter produced 347 million pounds of copper (28).

Consumption of copper is expected to grow at a rate of 3.2% compounded annually through 1980. To meet this demand, U.S. production must increase from the 1.5 million ton rate in 1971 to 2 million tons in 1980. Total rated capacity will then have to be 2.2 to 2.5 million tons annually. Some 400,000 to 700,000 tons per year of capacity must come from smelter expansions (4). The Anaconda Company produces approximately 10% of U. S. new copper (4).

During the next few years the smelters are expected to have an overabundance of concentrates available which will tend to hold concentrate prices down. The domestic market requires more copper than can be produced by domestic refiners, tending to raise the prices of their products (4). There was a rather dramatic copper price increase in 1973, with new copper selling for 60 cents per pound (27). The New York metals price for copper as of February 4, 1974, was 68 cents per pound.

F. Socio-Cultural

The town of Anaconda has a population of 9,770 persons. No census figures for the nearby communities of Opportunity, Silica, Sunnyside and Crackerville could be found. Warm Springs and Galen have populations of 500 and 50, respectively. All of these towns are in Deer Lodge County which has a population of 15,650. Powell and Silver Bow Counties have populations of 6,660 and 41,980 persons, respectively. Butte, the largest city in Silver Bow County, has a population of 23,370. Walkerville, a Butte surburb, has a population of 1,100. The city of Great Falls, where the anode copper is refined, has a population of 60,100. Cascade County has a population of 81,800. All figures are based on the 1970 census.

The Anaconda Company smelter employs approximately 1600 persons (7).

Although few persons living in the Butte vicinity are directly employed at the smelter, the Butte operations of the Anaconda Company employes approximately 1520 persons at the Berkeley Pit, 105 at the Continental East Pit, 830 persons in the 5 deep mines, about 200 office workers, 310 persons at the Weed Concentrator, and about 535 persons in the other small company groups (7). Some 78.2% of the concentrates and precipitates processed by the smelter come from the Butte mines (Table 1). In Anaconda's copper refinery and wire plants at Great Falls, some 750 persons are employed.

The Anaconda Company is the largest property tax payer in Silver Bow and Deer Lodge Counties. The Company's tax payments in these two counties are about $4.4 million and $1.9 million, respectively. The Company also pays property taxes of approximately $643,000 to Cascade County, approximately $43,000 to other counties and pays a metals mine tax of some $1.8 million to the state each year (7). Table 9 also shows some pertinent property tax information.

TABLE 9

Anaconda's Contribution to Local Property Tax Revenues in 1973

	Total Money Paid ($)	Paid by The Anaconda Co. ($)	Approximate % Paid by The Anaconda Co.
Property Taxes Received by Deer Lodge County	3,259,606 (Fiscal 72)	1.510,400 (Calendar 72)	46.3
	3,501,120 (Fiscal 73)	1,815,528 (Calendar 73)	51.9
Property Taxes Received by Silver Bow County	11,769,093 (Fiscal 72)	3,026,336 (Calendar 72)	25.7
		3,269,053 (Calendar 73)	-
Property Taxes Received by Cascade County	18,003,573 (Fiscal 73)	643,000 (Calendar 73)	3.6
Property Taxes Received by all Montana Counties		5,889,263 (Calendar 73)	

Note: This information was obtained from the Department of Revenue, State of Montana and Reference 7.

G. Energy Consumption

Total electric power consumption at the Anaconda Reduction Works, based on the first eight months of 1973 was 381,000 kilowatt-hours per day (KWhrs/day), 11.6 million KWhrs/mo., or 139 million KWhrs/yr. Of these total figures, about 60% or 241,000 KWhrs/day are directly used for the smelting of copper (2). This power is used in the different areas of the smelter in the following proportions (1):

electrostatic precipitator in main stack	375,000	KW Hrs/mo
660 T./day sulfuric acid plant	1,375,000	"
Transportation	35,000	"
Lime kiln no. 1	180,000	"
Lime kiln no. 2	555,000	"
Limestone quarry	30,000	"
Silica quarry	-	
Foundry	60,000	"
Roaster building no. 1	10,000	"
Roaster building no. 2	105,000	"
Reverberatory furnaces, converter and casting area	4,500,000	"
Miscellaneous	4,375,000	"
total	11,600,000	KW hrs/mo

Natural gas used at the smelter is as follows (1). These figures are also based on 1973 production except for miscellaneous which is from 1972 data. The gas quantities used are:

Roaster no. 2	30,100,000	ft.^{3}/mo
Reverberatory furnaces, converters and casting area	575,000,000	"
Foundry	7,000,000	"
Transportation	500,000	"
Acid Plant	50,000	"

Lime kiln no. 1	50,000,000 ft.^{3}/mo
Lime kiln no. 2	115,000,000 "
Electrostatic precipitators in main stack	250,000 "
Miscellaneous	130,350,000 "
Total	908,250,000 "

Fuel oil and gasoline consumption at the smelter is as shown below (1):

	Gasoline	Fuel Oil
Transportation	9,000 gal/mo	68,000 gal/mo
Limestone quarry	500 gal/mo	1,000 gal/mo
Silica quarry	1,000 gal/mo	500 gal/mo
Foundry	300 gal/mo	100 gal/mo
Reverberatory furnaces, converters, and casting area	150 gal/mo	-
Total	10,950 gal/mo	69,600 gal/mo

Consumption of fuel oil in the furnace area is for emergency use only and is used at a rate of 1,670 gal/hr.

In addition to the power consumptions given above, the Butte operations of The Anaconda Company uses 53 million KW hrs/mo of electric power, 430,000 ft.^{3}/mo of natural gas, 68,000 gal./mo of gasoline, and 15,700,000 gal./mo of fuel oil (1). These figures are again based on 1973 production. The copper refinery and wire plant at Great Falls use about 132 million ft.^{3}/mo. of natural gas, 7 million KW hrs/mo of electrical power, and very small amounts of gasoline and fuel oils (7).

H. Raw Materials and Other Natural Resources

Silica rock is currently being used at a rate of about 120 to 320 T./day or 54 to 144 cubic yards per day (yd ^{3}/day). This material is removed from the quarry about 3 miles Southwest of the smelter complex (5).

About 1,230 T./day or 496 yd^3/day of limestone is produced at the quarry west of town (5).

The Butte concentrates and precipitates require the mining of 50,000 T./day of ore from the Berkeley Pit and 2,700 T./day from the deep mines (1). Approximately 185,000 T./day of "overburden" are removed from the Berkeley Pit (1). The Company treats overburden as all material lying over the ore body and having no material value to the Company. About 14,000 T./day of ore are being removed from the Continental East Pit (79). This operation was begun quite recently; substantial amounts of waste material are removed from the operation.

I. Water Quality

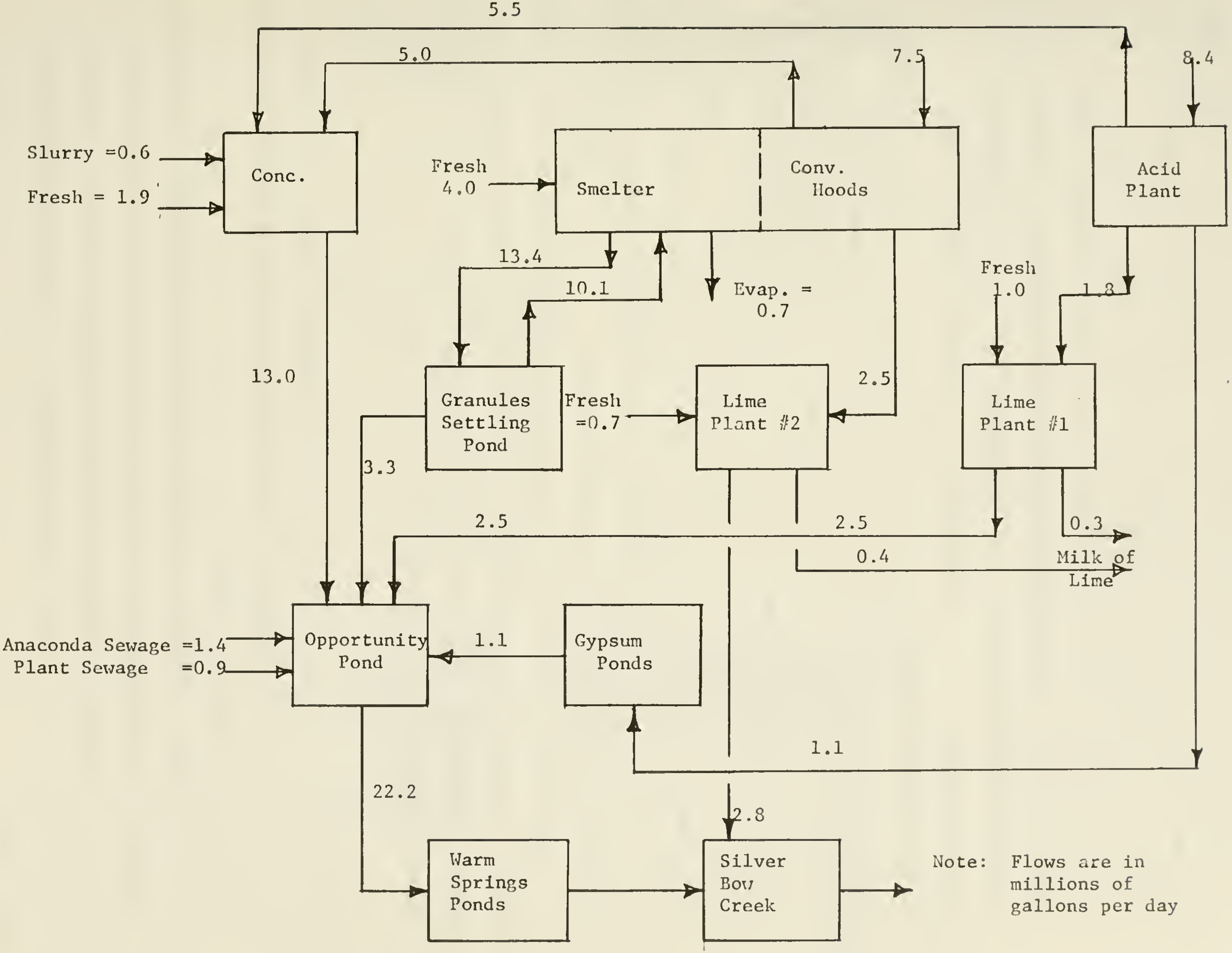
The water utilizing and wastewater producing facilities presently in use at the Anaconda Reduction Works include the concentrator, smelter, smelter acid plant, and two lime plants. The flow rates described below are also shown in Figure 10.

The concentrator uses approximately 12.0 million gallons per day (MGD) of water of which 1.2 MGD is fresh water. Recycled cooling water from the acid plant and the converter furnaces provides 10.5 MGD used at the concentrator. The remaining 0.3 MGD accompanies the concentrates from the Butte operations. The concentrator discharges approximately 12.0 MGD of wastewater (tailings plus the thickener overflows) to the Opportunity ponds.

The smelter uses approximately 21.6 MGD of water of which 11.5 MGD is fresh water and 10.1 MGD is recycled water from the granulation water clarification ponds. The converter hood cooling water is recycled at a rate of 5.0 MGD to the concentrator and 2.5 MGD to lime plant no. 2. The slag granulation water is discharged to the granulation water clarification ponds at a rate of 13.4 MGD. With the recycle of 10.1 MGD from these ponds, a new overflow of 3.3 MGD is discharged to the Opportunity ponds.

The smelter acid plant uses approximately 8.4 MGD of water consisting entirely of fresh water. The acid plant cooling water, 7.3 MGD, is recycled at a rate of 5.5 MGD to the concentrator and 1.8 MGD to lime plant no. 1. The remaining wastewater from the acid plant, a total flow of 1.1 MGD from the mist precipitators, scrubbers, hot fans, and acid plant is discharged to the gypsum pond. The gypsum pond overflows to the Opportunity ponds.

Figure 10. Water Usage at Anaconda Reduction Works, Anaconda, Montana



Note: Flows are in millions of gallons per day

Lime plant no. 1 uses approximately 2.8 MGD of water of which 1.0 MGD is fresh water and 1.8 MGD is recycled from acid plant cooling water. The wastewater from lime plant no. 1 is discharged to the Opportunity ponds at a rate of 2.5 MGD.

Lime plant no. 2 uses approximately 3.2 MGD of water of which 0.7 MGD is fresh water and 2.5 MGD is recycled from converter hood cooling water at the smelter. The wastewater from lime plant no. 2 is discharged to the lime ditch which discharged to Silver Bow Creek.

The Opportunity ponds cover an area of approximately 4,200 acres. In addition to receiving the wastewater discussed earlier, the Opportunity ponds receive the sewage from the City of Anaconda at a rate of approximately 1.4 MGD and the sewage from the smelter at a rate of approximately 0.9 MGD. The Opportunity ponds discharge via a siphon to the Warm Springs ponds. The Warm Springs ponds receive the discharge from the Opportunity ponds and, at times, the entire flow of Silver Bow Creek. Silver Bow Creek contains, in part, treated wastewater from the Anaconda Company-Butte operations and treated sewage from the Butte metropolitan area.

The Clark Fork River from the confluence with Warm Springs Creek to Cottonwood Creek is classified as C-D_2 which means the waters shall be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply. The April 19, 1973 results from the U. S. Geological Service sampling station are shown below. Metal analysis results are not yet available for the April 19, 1973 date. However, concentrations for April 18, 1972 are shown and should be about the same or lower for this period in time.

The Clark Fork River from Cottonwood Creek to the Little Blackfoot River is classified C-D_1 which means the waters should be maintained suitable for bathing, swimming and recreation; growth and marginal propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; and agricultural and industrial water supply.

The classification of the Clark Fork River below Garrison is $B\text{-}D_1$ which means the waters shall be maintained suitable for drinking, culinary and food processing purposes after adequate treatment equal to coagulation, sedimentation, filtration, disinfection and any additional treatment necessary to remove naturally present impurities; bathing, swimming, and recreation; growth and propagation of salmonid fishes and associated aquatic life, waterfowl and furbearers; agricultural and industrial water supply.

Clark Fork River near Galen on April 19, 1973

Stream Flow	99 cubic feet per second (cfs)
Water Temperature	7.0°C.
pH	8.3
Dissolved Oxygen	10.6 milligrams per liter (mg/l)
Biochemical Oxygen Demand	3.5 mg/l
Phosphorous (total)	0.04 mg/l
Nitrate and Nitrite total as N	0.29 mg/l
Nitrogen total as N	0.94 mg/l
Calcium	150 mg/l
Magnesium	18 mg/l
Sodium	16 mg/l
Chloride	8.1 mg/l
Fluoride	1.3 mg/l
Sulfate	380 mg/l
Coliform Bacteria	10/100 ml
Fecal Coliform	0/100 mg

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Stream Flow	221 cfs
Arsenic	0.010 mg/l (total)
Cadmium	0.004 mg/l (total)
Copper	0.020 mg/l (total)
Iron	0.670 mg/l (total)
Lead	0.012 mg/l (total)
Zinc	0.230 mg/l (total)

The principal sources of nitrogen in the Clark Fork River at this time are probably from the Butte "metro" treated sewage discharge and the Anaconda fish hatchery.

The Department is presently planning to take and analyze samples monthly from the Warm Springs pond discharge and from the Clark Fork River below Warm Springs Creek and below the Little Blackfoot River. The small amount of sampling information presently available indicates that the state's water quality standards are being met by The Anaconda Company. However, there is need for more data.

J. Effects on Materials

It has been found that sulfur dioxide in concentrations of 0.1 to 0.2 ppm can destroy certain paint pigments. Carbon steels, zinc, copper, aluminum and stainless steels are damaged by oxides of sulfur, especially at high relative humidities. The effects on iron were found at concentrations of 0.05 ppm. Sulfur oxides are also detrimental to portland cement, various stones, paper, leather and textiles. Textile fading studies have shown damage at 0.09 ppm sulfur dioxide (21).

IV. POSSIBLE ACTIONS BY THE DEPARTMENT OF HEALTH AND ENVIRONMENTAL SCIENCES

A. The Director may recommend that The Anaconda Company variance be granted by the Montana State Board of Health and Environmental Sciences as requested. The granting of any variance is permitted under Montana law only if the impact of such action neither endangers the public health nor endangers the public safety and, further, only if such action results in greater public benefit than public hardship to the citizens and state of Montana. Therefore, granting the variance would require the conclusion that The Anaconda Company's continuing, unabated violations of Montana's Clean Air Act and the regulations enacted thereunder are a danger neither to public safety nor to public health. Moreover, such action would also require the conclusion that the state is benefited more, or the hardship is less, from such continuing violations of Montana's air pollution laws than from compliance with the law.

B. The Director may recommend the denial of that variance request. No variance shall be granted except after a public hearing held after proper notice and until the Board of Health has considered the relative interests of the applicant, other owners or property likely to be affected by the emissions, and the general public. A variance is not a right of the applicant but shall be in the discretion of the Board. The Board can justifiably deny the variance after considering the facts established in the preceding sections of this statement. The variance can be denied as a result of any of the following conclusions:

1. The regulation sets a reasonable achievable standard.

2. Reasonably effective control systems are available.

3. Pollution control systems which will meet the standard do not require unreasonable economic expenditures.

4. Pollution control does not produce counter-productive environmental effects of greater magnitude.

5. The public health or safety is in jeopardy unless the variance is denied.

6. A public hardship is created unless the variance is denied.

7. No public benefit equals the public burden unless the variance is denied.

V. IMPACTS OF POSSIBLE ACTIONS

A. Grant the Variance as Requested

There would be no improvement to the present adverse environmental effect of continuing violation of the applicable regulations if the Company's variance request were granted. The company has not proposed any program to achieve compliance with the existing regulations at any time. Existing adverse environmental effects caused by continuing SO_2 violations are described in the preceding sections of this statement. Such continuing adverse environmental effects would continue to endanger public health and safety. The original adoption of the state sulfur emission regulations and the rejections of The Anaconda Company's request for changing these regulations in 1971 was based on the need to relieve the public of the well established ill effects of sulfur oxides in the air.

Because the Department concludes that granting the variance would continue to endanger the public's health and safety to an extent overshadowing any possible benefits it cannot recommend such action.

B. Deny the Variance

It is clear that the Company can achieve compliance with the applicable regulations. The cost of such compliance is consonant with what other similarly situated smelters have absorbed. If the Company does not voluntarily comply, Department enforcement and abatement would be necessary. Voluntary compliance would have no known significant adverse environmental impacts. Involuntary compliance might be more time consuming for the state and the public, but otherwise would have no known significant adverse environmental impact.

The Anaconda Company has implied it would close some of its operations if the variance request is denied. Such action would be a hardship on some part of the public, and would have no better environmental effect as full compliance, which could be achieved without strain to the public. It is the opinion of the Department that the likelihood of closure of the smelter operation of The Anaconda Company is remote, in any event.

REFERENCES

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APPENDIX A

(f) Definition:

"Btu" means British thermal unit which is the heat required to raise the temperature of one pound of water through one Fahrenheit degree.

(2) Primary Non-Ferrous Smelters

(a) No person or persons shall cause, suffer, allow or permit to be discharged into the outdoor atmosphere from any copper, zinc or lead smelting operation or any slag treatment plant reduced sulfur in excess of the amount shown in the following table:

Total Feed of Sulfur, lb/hr	Allowable Sulfur Emission, lb/hr Cu	Zn	Pb
1,000	100	100	100
5,000	500	394	348
10,000	1,000	704	593
20,000	2,000	1,270	1,000
40,000	4,000	2,310	1,000
60,000	6,000	3,210	1,000
80,000	8,000	4,120	1,000
100,000	10,000	5,000	1,000
Over 100,000	10,000	5,000	1,000

(b) For a total sulfur feed input between any two consecutive total sulfur feed inputs stated in the preceding table, maximum allowable emissions are shown in Figure 1 which follows this rule and by reference, is made a part of this rule. For the purposes hereof, total sulfur input shall be calculated as the aggregate sulfur content of all fuels and other feed materials whose products of combustion and gaseous byproducts pass through the stack or chimney.

(i) When two or more furnaces, sinter machines, sinter boxes, roasters, converters or other similar devices for converting copper, zinc or lead ores, concentrates, residues or slag to the metal or the oxide of the metal either wholly or in part are connected to a single stack, the combined sulfur input of all units connected to the stack shall be used to determine the allowable emission from the stack.

(ii) When a single furnace, sinter machine, sinter box, roaster, converter or other similar device for converting copper, zinc or lead ores, concentrates, residues, or slag to the metal or the oxide of the metal either sholly or in part is connected to two or more stacks, the allowable emission from all the stacks combined shall not exceed that allowable from the same unit connected to a single stack.

(c) The effective date of this section (2) for existing operations shall be June 30, 1973. For new operations, the effective date shall be June 30, 1970.

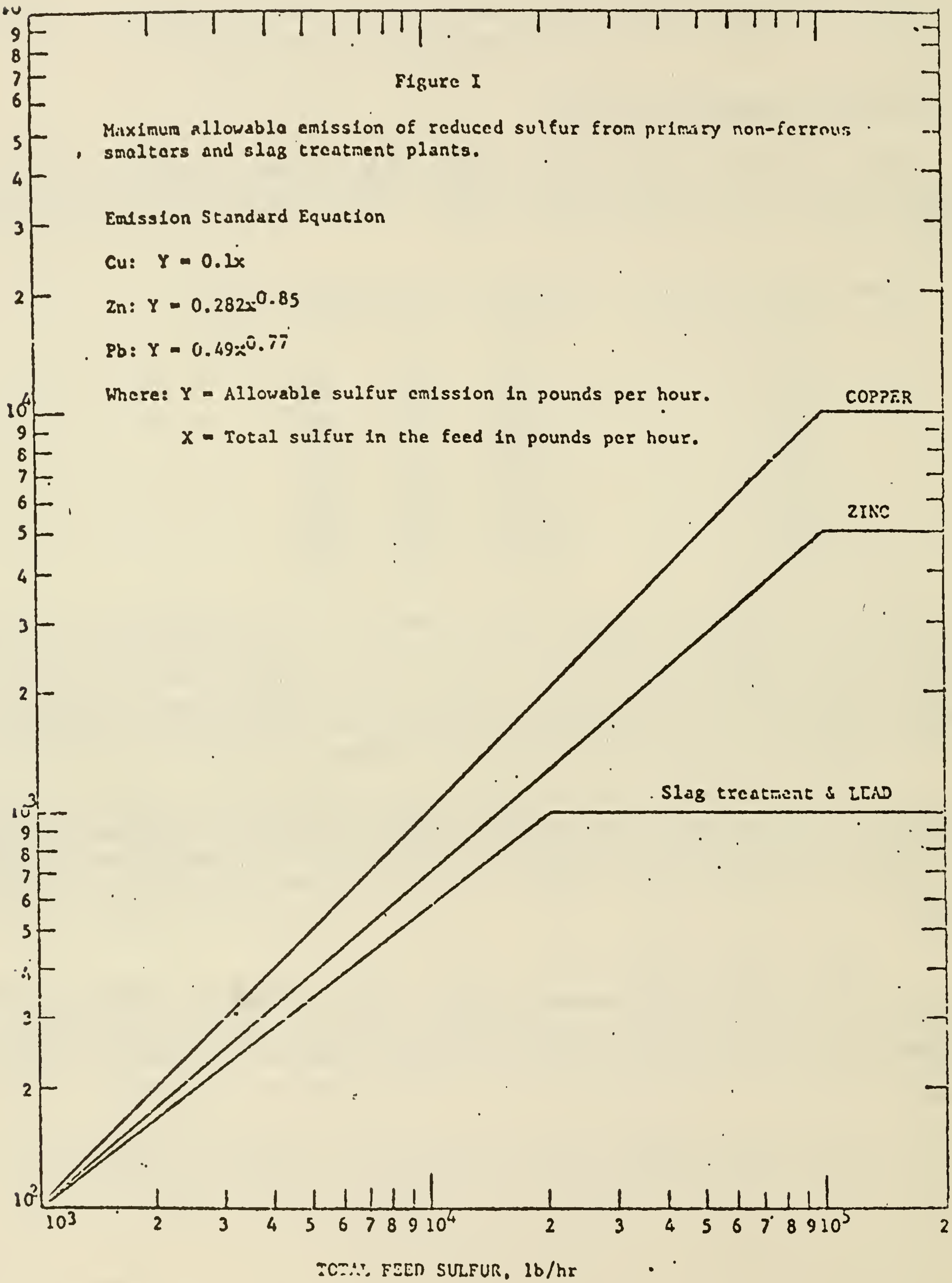

Figure I

Maximum allowable emission of reduced sulfur from primary non-ferrous smelters and slag treatment plants.

Emission Standard Equation

Cu: $Y = 0.1x$

Zn: $Y = 0.282x^{0.85}$

Pb: $Y = 0.49x^{0.77}$

Where: Y = Allowable sulfur emission in pounds per hour.

X = Total sulfur in the feed in pounds per hour.

16-2.14(1)-S1460 VISIBLE AIR CONTAMINANTS, RESTRICTIONS

(1) Restriction of Existing Installations

No person shall cause, suffer, allow or permit emissions from any installations which are:

(a) Of a shade or density darker than that designated as No. 2 on the Ringelmann Chart, or

(b) Of such opacity as to obscure an observer's view to a degree greater than does smoke described in subsection (1)(a) of this regulation.

This section does not apply to existing incinerators or existing wood waste burners.

(2) Restriction of New Installations and All Incinerators

No person shall discharge into the atmosphere from any single source of emission whatsoever any air contaminant:

(a) Shade or density darker than that designated as No. 1 on the Ringelmann Chart, or

(b) Of such opacity as to obscure an observer's view to a degree greater than does smoke described in subsection (2)(a) of this regulation.

(3) The provisions of sections (1) and (2) of this rule shall not apply to emissions during the building of a new fire, cleaning of fires or soot blowing, the shade or density of which is less than No. 3 on the Ringelmann Smoke Chart or of such opacity as to obscure an observer's view to a degree greater than does smoke designated as No. 3 on the Ringelmann Smoke Chart for a period or periods aggregating no more than four minutes in any 60 minutes.

Where the presence of uncombined water is the only reason for failure of an emission to meet the requirements of sections (1) and (2) of this regulation, such sections shall not apply.

The provisions of section (1) of this regulation shall not apply to the following:

(a) Transfer of molten metals.

(b) Emissions from transfer ladles.

16-2.14(1)-S14040 AMBIENT AIR QUALITY STANDARDS

(1) In accordance with section 69-3909, subsection 12 of the Clean Air Act of Montana, on May 27, 1967, the board adopted the Ambient Air Quality Standards shown below.

(2) Until additional pertinent information becomes available with respect to the effects of the substances listed below, the following air quality criteria shall apply in Montana.

Pollutants	Standards (Maximum permissible concentrations)
Sulfur dioxide[a]	0.02 ppm, maximum annual average 0.10 ppm, 24-hour average, not to be exceeded over 1 percent of the days in any 3-month period. 0.25 ppm not to be exceeded for more than one hour in any 4 consecutive days
Reactive sulfur (sulfation[b])	0.25 milligrams sulfur trioxide per 100 square centimeters per day, maximum annual average 0.50 milligram sulfur trioxide per 100 square centimeters per day, maximum for any one-month period
Suspended sulfate[c]	4 micrograms per cubic meter of air, maximum allowable annual average 12 micrograms per cubic meter of air, not to be exceeded over 1 percent of the time
Sulfuric acid mist[d]	4 micrograms per cubic meter of air, maximum allowable annual average 12 micrograms per cubic meter of air, not to be exceeded over 1 percent of the time 30 micrograms per cubic meter of air, hourly average, not to be exceeded over 1 percent of the time
Hydrogen sulfide[e]	0.03 ppm, ½-hour average, not to be exceeded more than twice in any 5 consecutive days

Pollutants	Standards (Maximum permissible concentrations)
	0.05 ppm, ½-hour average not to be exceeded over twice a year
Total Suspended particulate[f]	75 micrograms per cubic meter of air, annual geometric mean 200 micrograms per cubic meter of air, not to be exceeded more than 1 percent of days a year
Settled particulate (Dustfall[g])	15 tons per square miles per month, 3-month average in residential areas 30 tons per square mile per month, 3-month average in heavy, industrial areas
Lead[h]	5.0 micrograms per cubic meter of air, 30-day average
Beryllium[i]	0.01 micrograms per cubic meter of air, 30-day average
Fluorides, total (as HF) in air[j]	1 part per billion parts of air, 24-hour average
Fluorides (asF) in forage[k] for animal consumption - dry weight basis	35 parts per million
Fluorides (gaseous)[l]	0.3 micrograms per square centimeter per 28 days

[a] Sulfur dioxide measured by West-Gaeke or conductometric method.

[b] Sulfation measured by lead-peroxide candle

[c] Suspended sulfate measured by high volume sampler - turbidmetric procedure

[d] Sulfuric acid mist- Air Pollution Control District, County of Los Angeles, APCD - Sulfuric acid 13-49

[e] Hydrogen sulfide measured by methylene blue method - lead acetate tape for screening and monitoring

[f] Suspended particulate measured by high-volume sampler

[g] Dustfall measured by container open to atmosphere

[h] Suspended lead measured by high-volume sampler - dithizone and/or spectrophotometric procedures

[i] Suspended beryllium measured by high-volume sampler - fluorometric and/or spectrophotometric method.

[j] Total fluoride measured by impingers - Winter-Willard distillation procedure (SPADNS color)

[k] Forage cut, dried, ashed and subjected to Winter-Willard distillation procedure (SPADNS color)

[l] Gaseous fluorides measured by calcium formate paper technique in board standard shelter - Winter-Willard distillation procedure (SPADNS color)

The ambient air quality standards listed describe a level of air quality designed to protect people from the adverse effects of air pollution; and they are intended further to promote maximum comfort and enjoyment in use of property consistent with economic and social well being of the community.

Ambient air quality standards are used as a tool in achieving cleaner air, not as a license to permit unnecessary degradation of air quality which would thwart attainment of the long-range goal to maintain a reasonable degree of air purity.

These standards are not intended to represent the ultimate in air quality achievement. It is anticipated that research and development will gradually make possible cleaner air at lower cost. As evidence accumulates on deleterious effect of the contaminant, present objectives will be revised or additional standards established. The standards are designed to protect the health, welfare and comfort of the public and to minimize economic losses.

Because some pollutants combine chemically to form more harmful materials than the original emissions, ascribing a single effect to a single pollutant would be an erroneous over-simplification. The standards, therefore, apply to air containing a variety of pollutants. Although reaching the goals will result in benefits, no allowance for the time needed to achieve them was considered in their selection. They are intended to apply to areas where people live or where an adverse effect may occur.

The board, in adopting these standards, intends them to be goals and guidelines and so interprets the legislative intent of the word "standards" in section 69-3909 of the Clean Air Act of Montana.

(3) The sampling and analytical procedures employed to measure ambient levels of contaminants are to be consistent with obtaining accurate results which are representative of the conditions being evaluated. The sampling and analytical techniques enumerated may be used directly or employed as reference standards against which other methods may be calibrated.

APPENDIX B

BEFORE THE DEPARTMENT OF HEALTH

AND ENVIRONMENTAL SCIENCES

OF THE STATE OF MONTANA

In the matter of the application)
of the Primary Metals Division of)
The Anaconda Company, a Montana)
Corporation, for a variance from)
the sulphur oxide emission regu-)
lations applicable to the operation)
of its copper smelter at Anaconda,)
Montana)

PETITION FOR VARIANCE

In accordance with the procedural rules under Sub-Chapter 1 of Chapter 2 of the Department's Rules, the Primary Metals Division of The Anaconda Company (Petitioner) respectfully requests a variance and exemption from the sulphur oxide emission regulations pursuant to provisions of the Montana Clean Air Act as the same pertains to the operation of Petitioner's copper smelter at Anaconda, Montana.

1. The person authorized to receive service of notices for Petitioner is William P. Mufich, Counsel for Petitioner, whose address is 600 Hennessy Building, Butte, Montana 59701, and whose telephone number is (406) 723-4311.

2. Petitioner is an operating division of The Anaconda Company, a Montana corporation. Division officers include R. C. Weed, president; A. J. McDonell, executive vice president; M. K. Hannifan, vice president for operations; R. C. Cereghini, vice president for finance; and C. J. Hansen, vice president and chief counsel; headquarters of the Division is located at Kolb Road and Interstate 10, Tucson, Arizona and the mailing address is P.O. Box 11309, Tucson, Arizona 85734. The person in charge

of the smelter is Emil S. Kramlick, manager of the Anaconda Reduction Department, whose mailing address is The Anaconda Company, Anaconda, Montana 59711.

3. The type of activity involved is the operation of a pyrometallurgical copper smelter and it is located east of the City of Anaconda, Montana.

4. Petitioner's smelter treats copper concentrates and precipitates to produce anode copper. Feed material is dried and charged to reverberatory furnaces. Silica and lime flux is added to the feed in the reverberatories to accomplish smelting. These furnaces are fired by natural gas and operate at approximately 2000°F. The primary product from this reverbatory operation is molten copper matte. By-products include molten slag which is granulated and stored as solid waste and off-gases that contain sulphur dioxide, particulates, metal vapors and combustion products. All off-gases are routed through a common exhaust system. Copper matte is charged into converters where the remaining sulphur is oxidized and driven off into the main flue system. Blister copper which results from the converter operation is treated in a refining furnace and cast into anodes. Slag which is generated in converters returns to the reverberatories.

5. The regulation pertinent to this application is 16-2.14(1)-S1470(2) of the Montana Administrative Code relating to sulphur oxide emissions from primary non-ferrous smelters.

6. Compliance with the designated regulation is unreasonable because it is not possible for Petitioner, under the

present configuration of its smelter plant and control equipment, to restrict sulphur emissions to 10 percent of total feed as required by the regulation. Petitioner is now completing an environmental control program at the smelter for which the expenditure has been approximately $20 million. This includes construction of a 600 tons-per-day double-contact/double-absorption sulphuric acid plant for the treatment of converter gases, and the installation of a new flue and water-cooled hood system to exhaust converter gases. The hood system will provide a significant reduction in low-level fugitive emissions from the converter roof. When the acid plant, which is now being phased into operation, is at full capacity, the total sulphur retention will be 32 percent at the design production rate of 35 million pounds of copper per month. Retention of 90 percent, as required by the regulation, is not possible because only the converter gases are of sufficient strength for treatment in an acid plant, and only about 60 percent of the sulphur in the total plant feed reports to the converter. Gases from the reverberatories or other sources are not amenable to treatment in an acid plant. Since no facilities are available to Petitioner for the treatment or control of those gases by the compliance date or during the period of the requested variance, it is not reasonable to require Petitioner's compliance with the regulation.

7. The variance is requested for a period of one year. Petitioner seeks the variance so that it can continue the operation of its smelter during that period and also to provide time within which to continue the design and construction of

additional air quality control devices and systems at the smelter.

8. If compliance with the regulation were required on the effective date, Petitioner would be unable to comply with emission limitations and operation of the smelter would have to be disrupted.

9. As noted in prior paragraph 6, Petitioner's smelter will achieve a sulphur retention of 32 percent when the acid plant becomes fully operational. It is expected that this will be accomplished during July of 1973. Petitioner also has started construction of a hydrometallurgical plant which will utilize its Arbiter process and be operated as a part of Petitioner's smelter complex at Anaconda, Montana. This facility will produce 100 tons per day of cathode copper from sulphide concentrates but it will not generate any sulphur oxides. The Arbiter plant also will selectively accomplish a reduction in sulphur feed to the existing smelter and an equal reduction of sulphur emissions to the atmosphere. When the Arbiter plant becomes operational, in late 1974, approximately 50 percent of the total sulphur feed to the smelting complex will be retained. The cost of the Arbiter plant will exceed $25 million. Additionally, Petitioner has under design for its smelter the installation of a fluo-solids roaster to replace the drying furnace and the installation of an electric furnace to replace the reverberatory furnaces. The estimated cost of these further environmental controls is approximately $33 million. Completion of these installations cannot be achieved until late in 1975. At that time, the gas and particulate loadings in the exhaust will be materially different than that

which exists now. Petitioner believes that following completion of this control program, a reasonable period of operation should be allowed to determine the results achieved by these installations upon the consist and retention of emissions. It is difficult to determine at this date what further control devices or procedures may be available and operationally feasible after construction and testing of the program Petitioner now has under way. While the electric furnace installation could enable some further retention through treatment of gases by additional sulphuric acid plants, this may well result in severe adverse impacts upon the environment. Through use in its mining operations and potential sale, Petitioner hopes to be able to dispose of its scheduled production of 600 tons per day of sulphuric acid from its present acid plant. However, if additional acid production were required, it could not be disposed of by sale under present market conditions for sulphuric acid. This additional acid would have to be neutralized, creating significant solid waste disposal problems, requiring undue consumption of other resources, and adding substantially to the cost of operation.

10. The advantages to the residents of Montana resulting from the granting of the requested variance would be, primarily, the uninterrupted operation of the smelter and the continuation of the current construction program. Petitioner's plant constitutes the major source of employment in the Anaconda area and any disruption of smelter operations would impose severe economic hardships upon the residents of the community. Petitioner directly employs more than 1400 persons in its operations at Anaconda, with

a total annual payroll of approximately $20 million. It is the main source of tax revenue and the principal purchaser of gas, power, freight and supplies in the area. Expenditures for environmental controls alone will amount to $53 million through 1975 and construction of the Arbiter plant will increase that total to at least $78 million. The smelter produces 35 million pounds of copper per month and the loss of that supply would cause extreme difficulties for numerous manufacturing and fabricating firms who rely upon Petitioner to furnish essential amounts of copper. If operation of the smelter had to be discontinued for any period of duration, Petitioner's mining, refining and railroading operations in Butte and Great Falls, Montana also would have to be drastically curtailed or even closed because the smelter is essential to both the mining and refining operations. More than 4500 citizens of Montana are employed in these other operations and the impact of the loss of these jobs would be extremely detrimental to the economy of the entire State. A substantial number of persons now working in construction projects or for suppliers to Petitioner also would be adversely affected.

11. The operation of Petitioner's smelter under the requested variance would not constitute a nuisance. Evaluation of measurements of SO_2 concentrations over the past seven months demonstrates that Petitioner's control program will be entirely adequate to meet the national ambient air quality standards established by the Environmental Protection Agency.

12. Petitioner has no knowledge of any case pending in any Montana court, civil or criminal, relating to the identical

equipment or process involved in this application. Petitioner is the plaintiff in an action entitled "The Anaconda Company vs. Ruckelshaus, et al" filed in Federal District Court in Denver, Colorado, by which Petitioner contested the promulgation of certain proposed emission standards applicable to Petitioner's smelter by the Environmental Protection Agency. After a ruling favorable to Petitioner, the Government appealed and the matter is now pending before the U.S. Court of Appeals for the Tenth Circuit at Denver and is designated as Cause No. 72-1272.

13. Petitioner has obtained a construction permit from the Department for the acid plant erected in connection with its control program.

Petitioner respectfully submits that in view of the facts presented in this application, the variance sought herein should be granted.

THE ANACONDA COMPANY
Primary Metals Division

By CJ Hansen
C. J. Hansen
Vice President and
Chief Counsel

APPENDIX C

6.1.2 Cost Analysis of Alternative Control Strategies

6.1.2.1 Control cost analysis

Introduction

The financial expenditures necessary to control sulfur dioxide emissions are developed in this section for four basic types of pyrometallurgical smelters. Cost estimates are developed for capital expenditures based on the construction of new town-site smelters. Additionally, various control alternatives achieving sulfur dioxide control efficiencies from 70 to 99^+ percent (assuming total capture by exhaust hoods, no fugitive emissions, and no downtime in control equipment) are costed for these four basic smelter types.

Model plant characteristic

The model smelter is based on processing 1000 tons per day of new metal bearing material of the following analysis:

1. Copper (Cu) - 27%
2. Iron (Fe) - 28%
3. Sulfur (S) - 32%
4. Silica - 8%
5. Alumina - 2%
6. Lead, Zinc, Other - 3%
7. Precious Metal Values - minute quantities

Based on discussions with consultant engineers, it appears that a smelter of this capacity is representative of the smallest viable operation that could be built today.(9) Thus, in this respect, this development is biased somewhat toward identifying high costs with various levels of sulfur dioxide control, since larger installations would be able to take advantage of the inherent "economics-of-scale" associated with building large sulfur dioxide control systems. The concentrate analysis, however, may be considered "typical" of concentrates available in the southwestern United States. Although variations in concentrate analysis such as the ratio of copper to sulfur for example, significantly influence the control costs associated with various levels of sulfur dioxide control, these variations are not taken into account. Rather than examine the extremes, or biasing the results toward one extreme or the other as in the case of smelter capacity, the development is based on an "average" or "typical" concentrate which should lead to "average" or "typical" control costs. Consquently, the control costs developed are considered to represent, for the most part, "average" or "typical" order-of-magnitude costs.

The model smelter produces approximately 86,000 tons of copper per year (260 tons per day) and generates 620 tons per day of sulfur dioxide. This assumes a 2 percent loss of copper and 3 percent loss of sulfur in slag products.

Plant economics

Capital

Order-of-magnitude estimates of capital investment have been developed based on the available literature, and contact with construction firms, consultants, industry representatives, and the American Mining Congress. Tabulated costs of various elements in the construction of the basic four types of smelters are presented in Table 6-10, in 1973 dollars.

The data in Table 6-10 are assembled to show the total capital for a grass roots smelter, added capital for pollution control (all off-gases), and town-site investment requirements. Cost data for new, complete town-site smelters for the four basic technologies are as follows:

Technology	Capital ($ millions)
1. Flash Smelting	99-108
2. Hot Calcine Reverberatory Smelting	100-112
3. Green Charge Reverberatory Smelting	98-110
4. Electric Furnace Smelting	90-98

These data show that flash smelting and electric smelting have a slight advantage in lower capital requirements than the conventional reverberatory smelting methods. However, there are situations where the flash or electric smelting may not be as viable as the above capital costs suggest. For example, in Arizona electric power is presently not available to any potential newcomers desiring to plan an electric smelter[1] and with flash smelting, high lead and zinc levels in the concentrates may require special design (higher cost) in the waste heat boiler section of the flash furnace.

TABLE 6-10 ELEMENTS OF CAPITAL COSTS FOR SMELTER TECHNOLOGIES
($1000's)

Total Direct Costs	Flash Smelter	Electric Furnace Smelter	Green Charge Reverb Smelter	Hot Charge Reverb Smelter	Comments
A Concentrate & Flux Handling	1600	1600	1600	1600	
B Dryer & Air Preheater	1280	1280	----	----	
C Furnace & Waste Heat Boiler	5900	5300-6700	4600	4700	Electric Furnace Includes Substation, No Waste Heat Boiler
D Flue Gas & Dust Handling	1900-3400	1600-2700	3000-5300	2100-3800	Hot Gas Fans, Electrostatic Precipitators, High Velocity Flues, Dampers, Gates, Radiant Cooling
E Converter Aisle	5000	5000	5000	5000	Includes 3-13x30 Pierce Smith Converters, Converter Crane, Platforms, Blowers, Conventional Uptakes
F Anode Casting Facility	1200	1200	1200	1200	2 Holding Furnaces, Casting Wheel
G Fluo-Reactor	----	----	----	3400	
H Power Plant	2700	----	4000	2900	
I Slag Plant	2700	----	----	----	
J Miscellaneous Facilities	1300	1300	1300	1300	
K Site Clearance	1100	1100	1100	1100	
L Electrical Wiring	2100-3400	2100-3400	2100-3400	2100-3400	
M Buildings & Plant Facilities	1100-2100	1100-2100	1100-2100	1100-2100	
Total Direct Costs	30,000	24,100	37,300	28,600	

TABLE 6-10 (Con't) ELEMENTS OF CAPITAL COSTS FOR SMELTER TECHNOLOGIES

Total Direct Costs	Flash Smelter	Electric Furnace Smelter	Green Charge Reverb Smelter	Hot Charge Reverb Smelter	Comments
Construction, Supervision & Equipment	4500	3600	4100	4300	15% of Direct Costs
Engineering & Home Office	4200	3400	3800	4000	14% of Direct Costs
Indirect Costs	10,500	8500	9500	9900	Start-up Contingency, Administrative, Expenses, Fees (35% of Directs)
Total Capital	49,100	39,600	44,700	46,800	
Added Capital for Pollution Control	12,800-16,000	12,800-16,000	16,000-22,500	16,000-22,500	Required to Achieve 90-95% Control(1) (excluding acid neutralization)
Added Capital for Townsite Smelter	37,500-42,800	37,500-42,800	37,500-42,500	37,500-42,800	Land, Townsite, Utilities (Town), Waste Treatment Plant, Highways, Railroads, Office Buildings, Warehouse, Maintenance, Power Plant (Town & Smelter), Wells, Slag Disposal Area

SOURCES:

(a) Flash furnace technology - References 1, 2, and 3.
(b) Electric furnace technology - References 4 and 3.
(c) Conventional reverberatory smelting technology - References 1 and 6.
(d) General cost information on auxillary equipment - References 3, 6, and 5.

Notes:

(1) Assuming total capture by exhaust hoods, no fugitive emissions and no downtime of control equipment.

Operating Costs

Order-of-magnitude estimates are presented here for the direct operating costs of flash smelting vs conventional green charge reverberatory smelting:

Item	Flash Smelter ($1000's)	Green Charge Smelter ($1000's)	Unit Cost
Supervision	132	168	$12,000/yr
Operating Labor	1001	889	$3.75/hr
Fuel	235	915	40¢/MCF
Power	366	--	1¢/kwh
Flux	456	1630	$15/ton
Maintenance Labor	443	375	$3.75/hr
Supplies	455	465	---
Copper Losses (Slag)	688	1380	50¢/lb
Steam Credit	(105)	--	1¢/kwh
Total (Actual)	3671	5822	
(Unit Basis)	2.1¢/lb	3.4¢/lb	

SOURCE: Lummus International

These data suggest a cost advantage, of 1.3 cents credited to flash smelting, although discussions with the Magma Copper Company indicate that cost advantages narrow to 0.4-0.5 cents. However, this does not take into account pollution control, plant overhead, plant amoritization, nor refining and shipping. Slag treatment costs (direct operating expenses) are included for flash smelting.

Control alternatives

The problem of controlling emissions of sulfur oxides from copper smelters has many facets in an economic sense. The difficulty of pollutant capture is one of those facets. Pollutant removal from the gas stream and its ultimate disposal constitute another facet to the overall problem of controlling smelter gas. To provide an overview of these facets, the economics associated with several control alternatives for each of the four basic types of pyrometallurgical smelters were developed. Sulfuric acid plants, sulfur plants and dimethylaniline (DMA) scrubbing units comprise the basic process modules used to construct the various control alternatives.

Due to the potential oversupply problems inherent in sulfuric acid manufacture at the western copper smelters, neutralization requirements were analyzed in those control alternatives incorporating acid plants.

The assumption of free, unlimited limestone is made in the analysis and capital and operating cost requirements have been developed from industry data.[(10)]

Sulfur plants were included in several of the control alternatives as an alternative to the production of sulfuric acid. The economics are based on sulfur plant technology similar to that commercialized by Allied Chemical at the Falconbridge Nickel smelter in Canada.

In order to limit the number of models developed, only DMA scrubbing was considered in this analysis. It is expected that the costs associated with DMA scrubbing are similar to those associated with other scrubbing systems such as sodium sulfite/bisulfite and ammonia. This scrubbing system produces a concentrated sulfur dioxide stream (∿ 100%) which can be used as feed to a sulfuric acid plant or sulfur plant.

Control cost of alternatives

The first step toward determining cost requirements of various control alternatives is to examine the basic process modules mentioned above, which are used to construct the various control alternatives. Capital estimates for turn-key projects derived for typical flowrates of either total gas or sulfur are presented in Table 6-11 with their respective scale exponents for extrapolation. The data have been scaled to 1973 dollars by using an annual inflation rate of 6.7 percent in construction costs. The information source for basis of the estimate is cited. Site clearance and hook-up of available off-site facilities are included in the estimates.

Operating costs are also presented in Table 6-11. The literature basis for utility requirements are referenced. Prices of utilities and labor have been taken as assumed in the Fluor study(11) which developed the earlier mentioned utility requirements. Prices of commodities are based on current quotations in the Oil, Paint, and Drug Reporter (October 1972).

Various combinations of emissions control processes were assembled for the four basic smelter type configurations and are presented in Figures 6-3 through 6-6. Based on physical process parameters developed from material balance data, cost estimates were derived for these control

TABLE 6-11 CAPITAL COSTS AND OPERATING REQUIREMENTS FOR CONTROL PROCESSES

	Single Stage Acid Plant	Dual Stage Acid Plant	Elemental Sulfur Plant	Elemental Sulfur Plant	Dimethylaniline Absorption	Wet Cleaning Plant[2]	Unit Cost Factors
Plant Size	100,000 SCFM	100,000 SCFM	15,000 lb sulfur/hr (90% SO_2 in feed)	15,000 lb sulfur/hr (15% SO_2 in feed)	50,000 SCFM (5% SO_2 in feed)	50,000 SCFM	
Capital, $MM[1]	9.00	10.3	2.56	5.60	12.0[3]	2.54	
Capital Scale Factor	0.63	0.63	0.58	0.58	0.70	0.68	
Basis for Capital Estimate	Ref. 12	Ref. 14, 15	Ref. 8	Ref. 8	Ref. 7, 16	Ref. 12	
Basis for Utils.	Ref. 12	Ref. 15	Ref. 8	Ref. 8	Ref. 12, 8	Ref. 12	
Direct Operating Items							
Methane			13.4 MCF/Ton S	18.4 MCF/Ton S			40¢ per 1000 MCF
Electricity	4020 kw	4800 kw	40 kwh/Ton S	181 kwh/Ton S	1230 kw	300 kw	1¢ per kwh
Steam					14.7 Mlbs/hr		80¢ per Mlbs
DMA					12.6 lb/hr		26¢ per lb
Caustic Soda							$80 per ton
Soda Ash					0.20 ton/hr		$35 per ton
Sulfuric Acid					0.23 ton/hr		$15 per ton
Process Water	50,000 gal/hr	50,000 gal/hr		860 gal/ton S			50¢ per 1000 gal
Raw Water						25,000 gal/hr	25¢ per 1000 gal
Cooling Water	224 gal/ton S	224 gal/hr S	1700 gal/ton S	3600 gal/ton S	103,000 gal/hr		5¢ per 1000 gal
Catalysts			3.8 lb/ton S	3.8 lb/ton S			13¢ per lb
Operating Labor	72 manhours/day	72 manhours/day	54 manhours/day	54 manhours/day	24 manhours/day	24 manhours/day	$5 per manhour
Maintenance	6% of Capital	6% of Capital	5% of Capital	5% of Capital	6% of Capital	8% of Capital	

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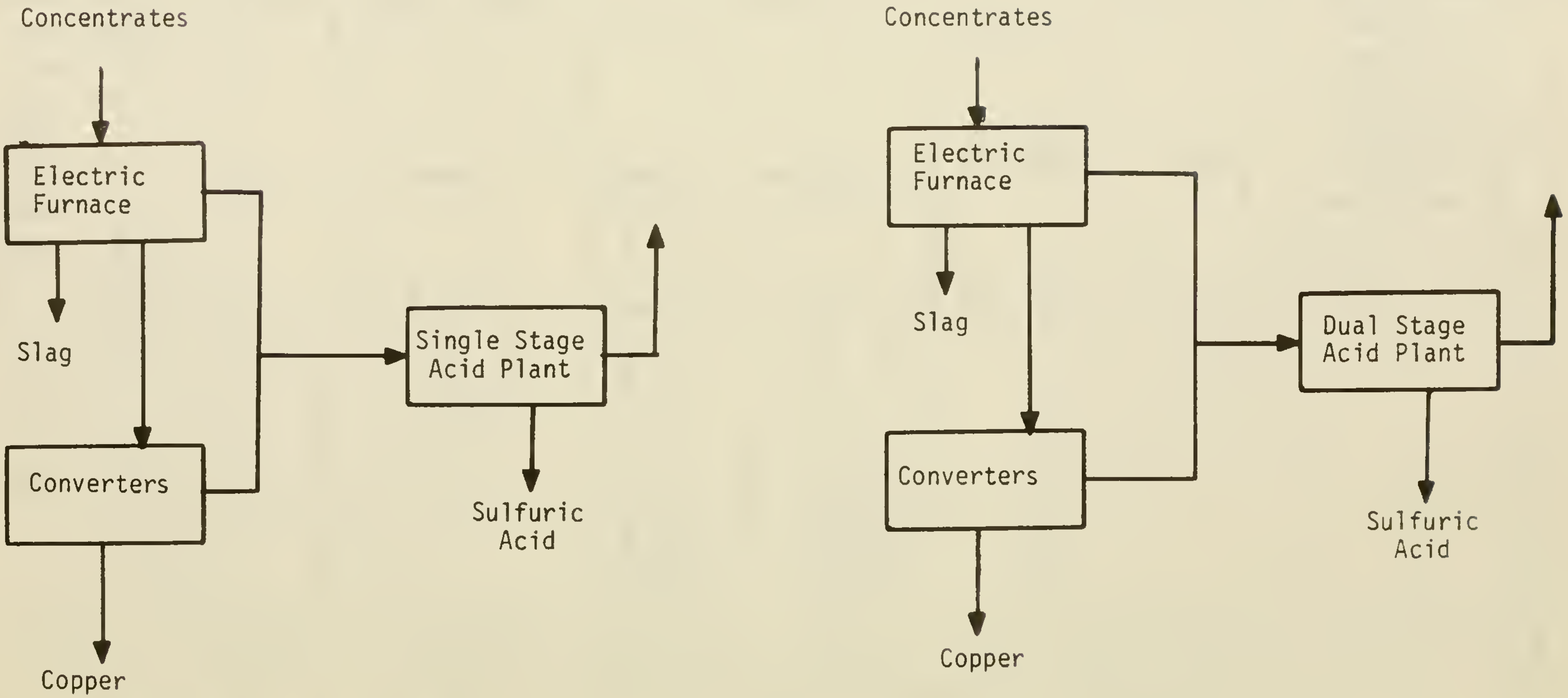
(1) Battery limits costs, including site clearance and hook-up of available off-site facilities.

(2) Wet cleaning plant capital must be added to capital for DMA and Sulfite/Bisulfite scrubbing units that receive smelter off-gas directly.

(3) Capital for a plant accepting 1.5% SO_2 feed (50,000 SCFM) would be $9.1 MM; operating requirements remain same as reported for the plant here with feed.

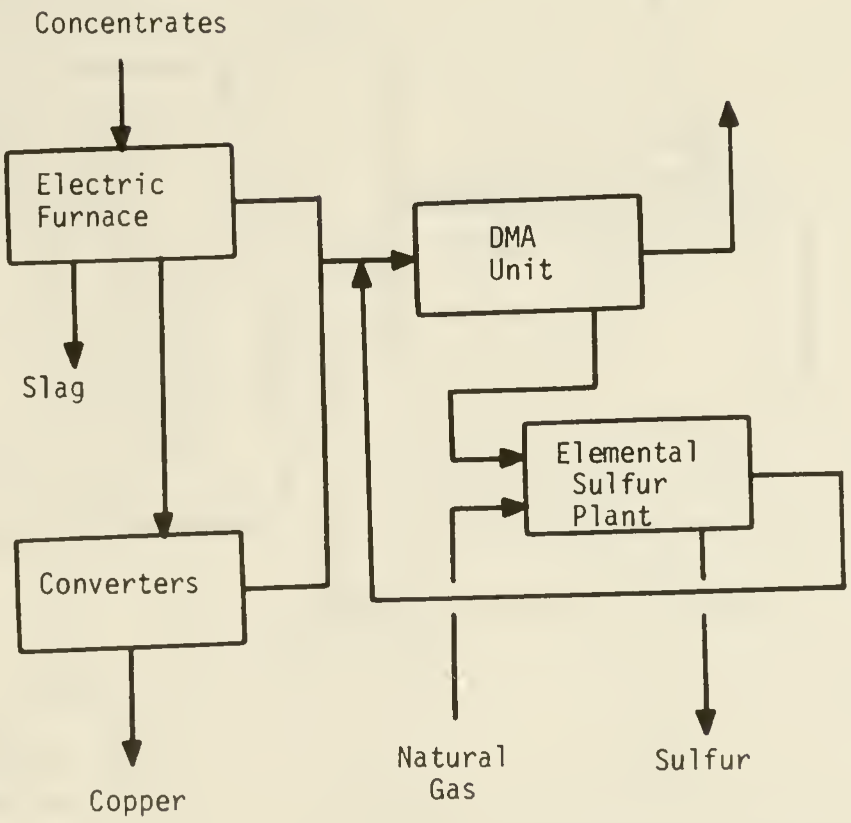
Figure 6-3 Model copper smelting facilities-electric smelting options


Case I(a)

Case I(b)

Figure 6-3 (Con't) Model copper smelting facilities-electric smelting options

Case I(c)



Case I(d)

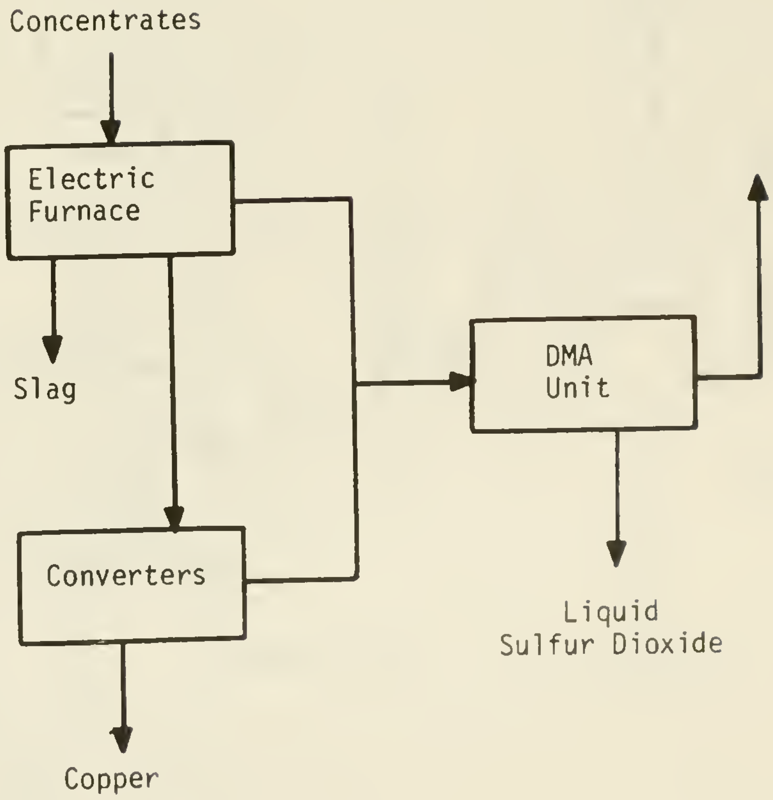
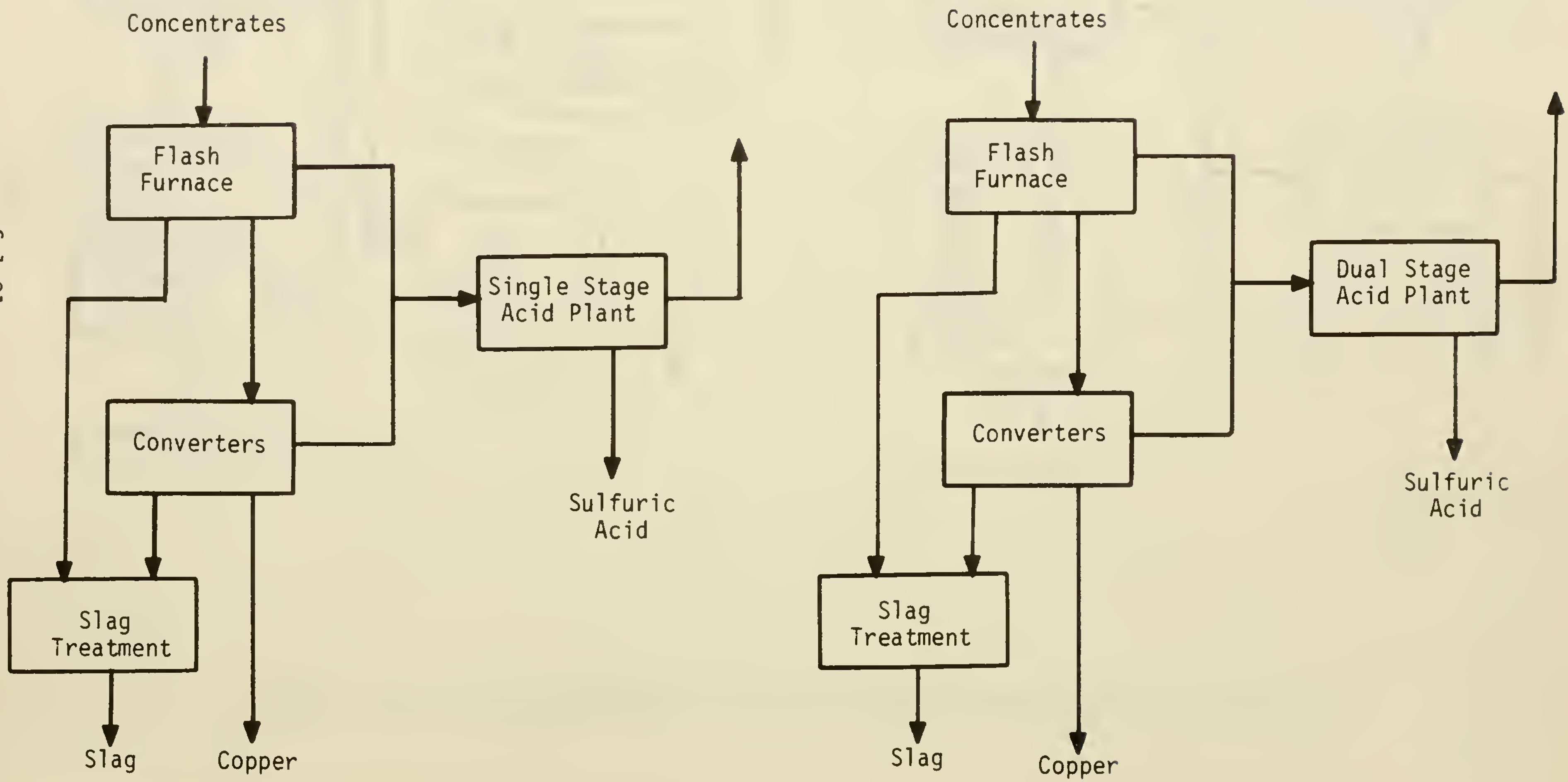
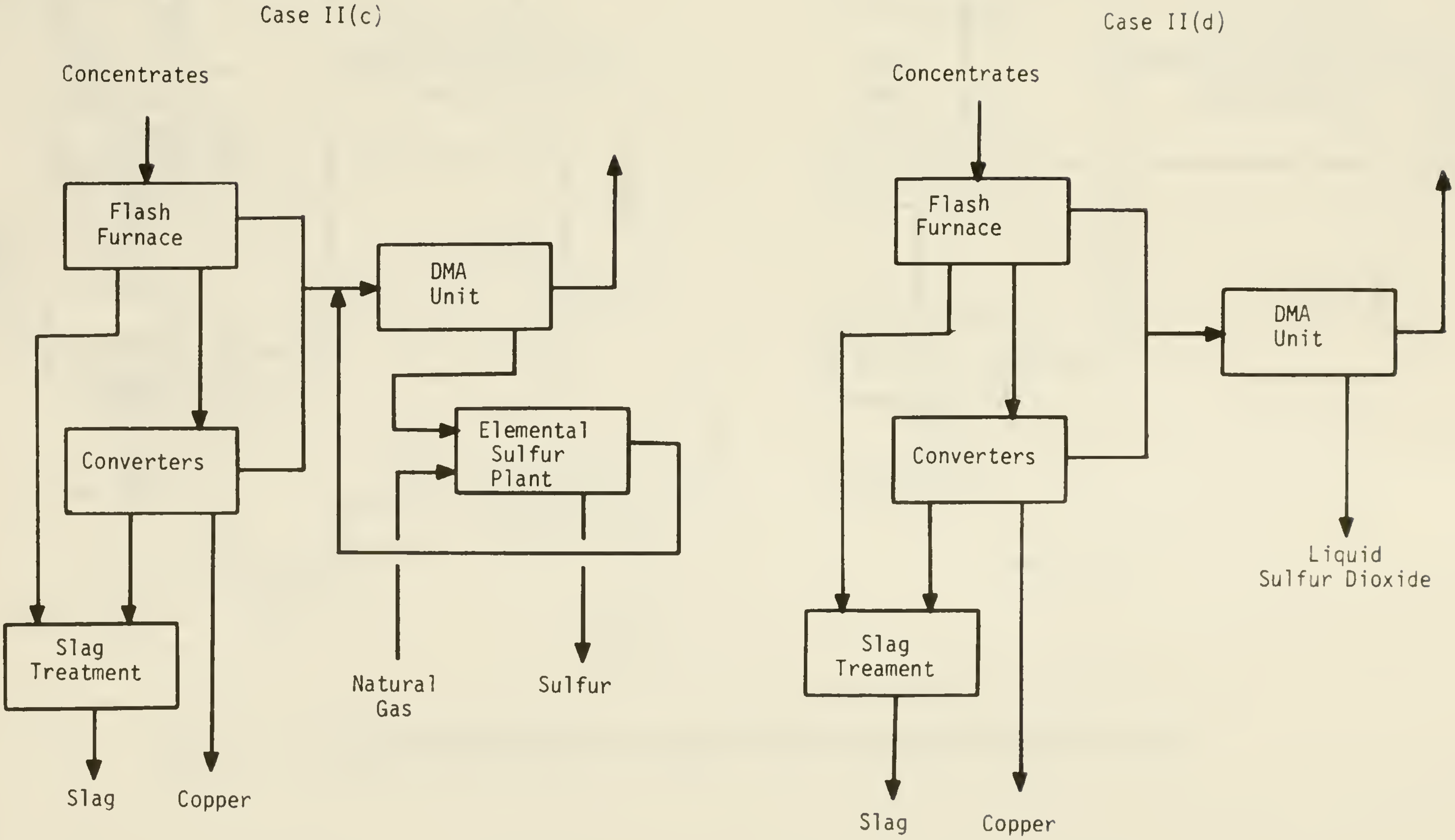


Figure 6-4 Model copper smelting facilities-flash smelting options.


Case II(a)

Case II(b)

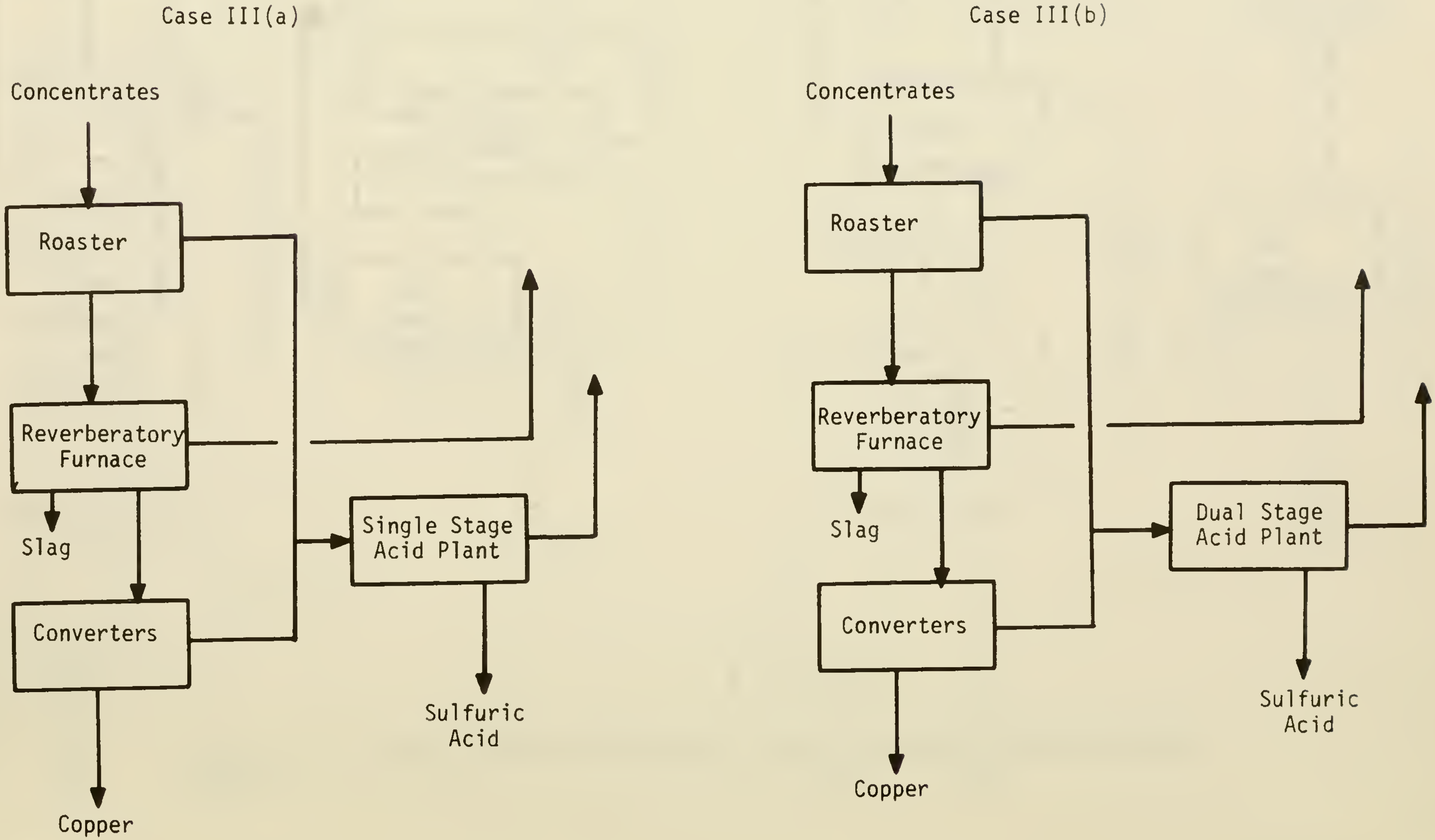
Figure 6-4 (Con't) Model copper smelting facilities-flash smelting options.



Case II(c)

Case II(d)

Figure 6-5 Model copper smelting facilities-roaster/reverberatory smelting options.



Case III(a)

Case III(b)

Figure 6-5 (Con't) Model copper smelting facilities-roaster/reverberatory smelting options.

Case III(c)

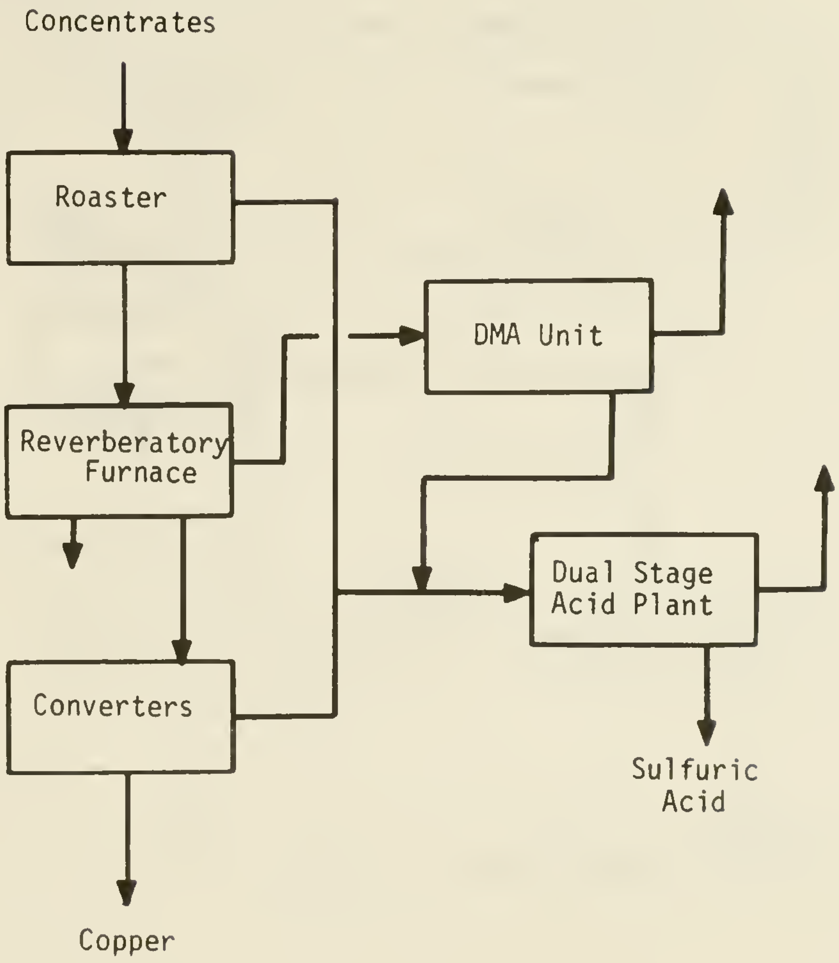
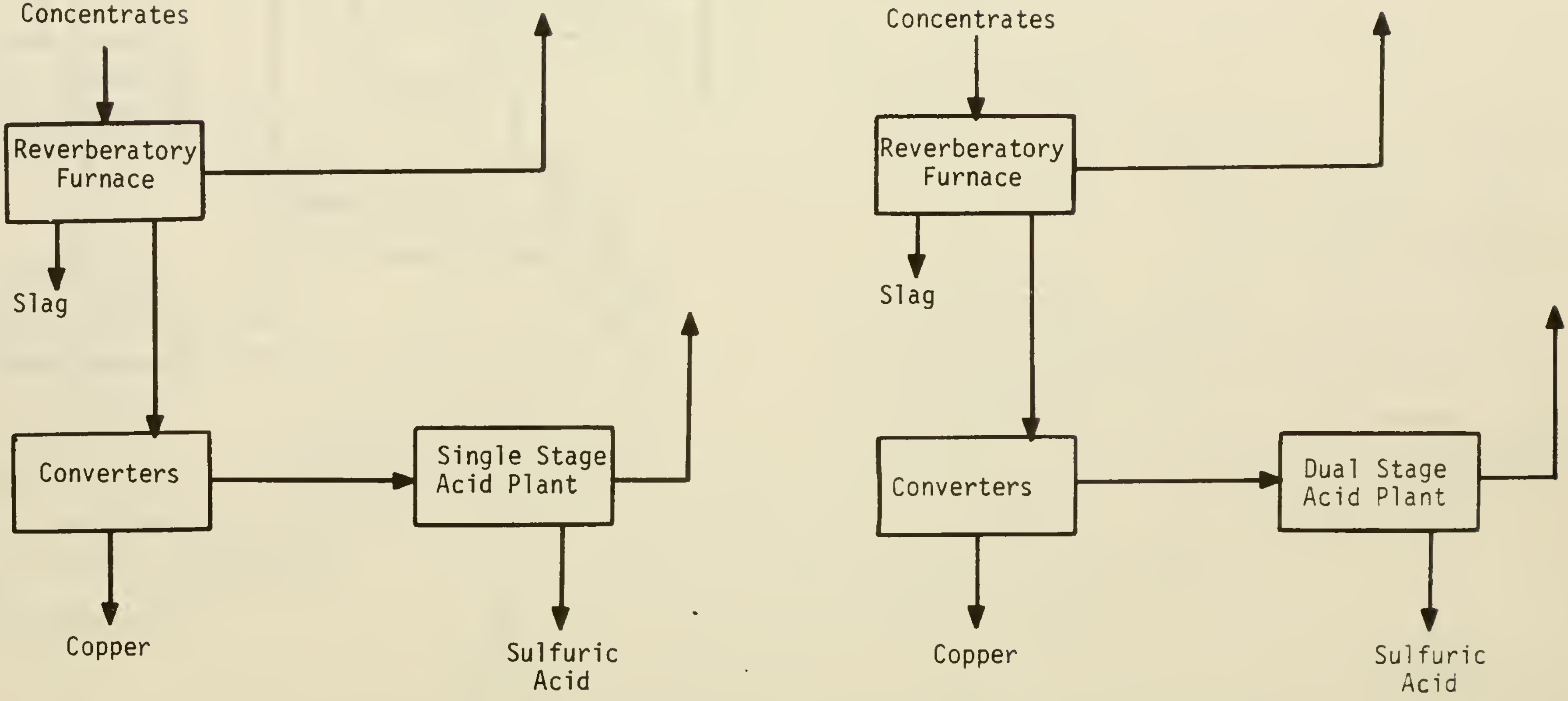


Figure 6-6 Model copper smelting facilities-reverberatory smelting options.

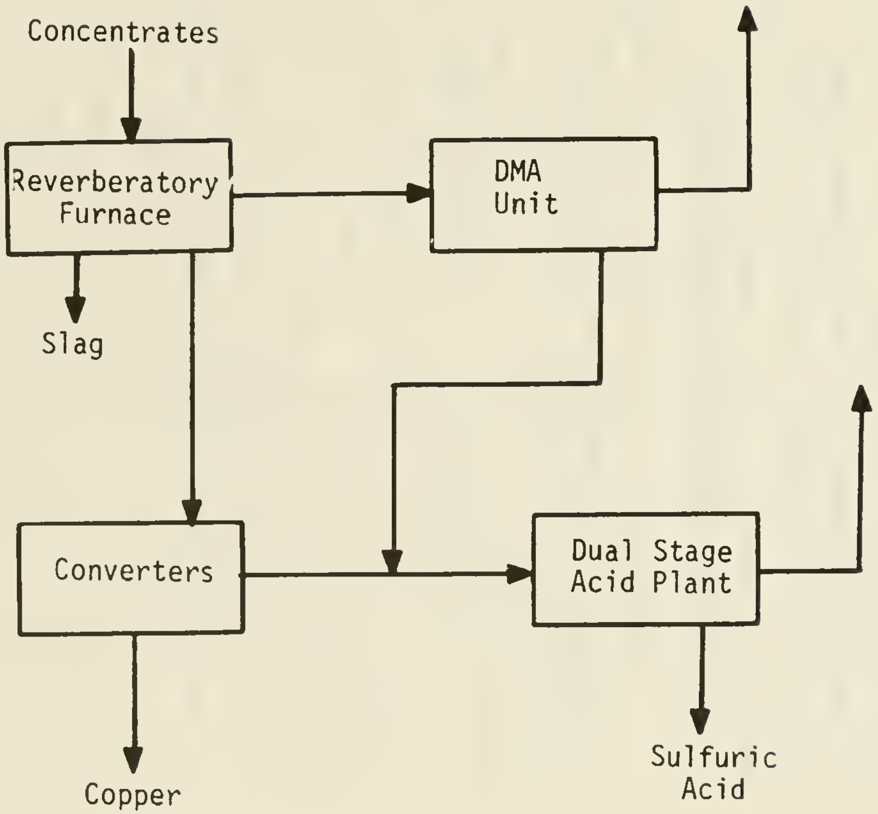


Case IV(a)

Case IV(b)

Figure 6-6 (Con't) Model copper smelting facilities-reverberatory smelting options.

Case IV(c)



combinations. Total capital and operating costs are presented in Table 6-12. In addition, the overall control of sulfur dioxide emissions, expressed as a percent, achieved with each control alternative is summarized. It is to be noted, however, that these percentages are theoretical in nature and are based on the assumptions of total capture by exhaust hoods with no fugitive emissions and no downtime of the control system. As a result, these overall control efficiencies are not representative of what could be achieved in actual practise, but are for discussion or comparative purposes only. For example, a recent EPA survey revealed fugitive emissions varying between 0% to 15% at existing domestic smelters.

Table 6-12 also presents control costs expressed in terms of cents per pound of copper produced and in terms of cents per pound of sulfur dioxide controlled. Finally, this table also presents various incremental control costs in terms of incremental cents per pound of copper produced and in terms of incremental cents per incremental pound of sulfur dioxide recovered. The basis for these incremental costs is explained in the footnotes to the table.

The costs presented represent incremental costs associated only with the treatment of pollutants. The cost of tight fitting, water cooled hoods have been included although other pieces of gas collection devices, such as headers, balloon flues, and ducts have not. Cost differences relevant to the various modes of furnace and converter operations have not been taken into account.

The derivation of the capital related charges is based on the following assumptions: (1) depreciation of 15 years (25 years for neutralization facility) for all equipment, (2) interest, insurance, and taxes at 10 percent of total invested capital, and (3) maintenance costs, estimated as percents (see Table 6-11 for actual percents) of total invested capital. Operating costs are the direct operating expenditures for payroll costs and utilities. The unit costs are based on production of 86,000 tons of copper per annum (1.[illegible] × 10[illegible] #/yr)

For all control alternatives, each smelter consists of one furnace to smelt 1000 tons per day of concentrate and 3 Pierce-Smith converters. Wet cleaning units consisting of scrubbers, mist precipitators, etc. are mandatory for treating all smelter source emissions. Metallurgical acid plants sold as turnkey units incorporate this feature. Therefore, wet cleaning requirements for acid plants are included in acid plant costs wherever such a plant is sized and costed. A brief discussion of each control alternative follows.

TABLE 6-12 CONTROL COSTS FOR MODEL COPPER SMELTING FACILITIES

Model No.	Control Equipment	Capital Cost ($MM)	Capital Charges ($MM/yr)	Operating Cost ($MM/yr)	Total Cost ($MM/yr)	Overall Control (%)	Control Costs Cents/lb Copper	Control Costs Cents/lb SO$_2$	Incremental Control Costs Δ Cents/Δ lb Copper	Incremental Control Costs Δ Cents/Δ lb SO$_2$
	Electric Smelting									
Ia	Single Stage Acid Plant Neutralization	10.2 5.4 15.6	2.31 0.96 3.27	0.57 0.97 1.54	2.88 1.93 4.81	97.5(1) 97.5(1)	1.68(2) 2.79	0.72(2) 1.21	— —	— —
Ib	Dual Stage Acid Plant Neutralization	11.4 5.5 16.9	2.59 1.00 3.59	0.62 0.99 1.61	3.21 1.99 5.20	99.5(1) 99.5(1)	1.87(2) 3.03	0.79(2) 1.28	0.19(3) 0.24(3)	4.34(3) 5.13(3)
Ic	DMA Scrubbing Sulfur Plant	25.8 3.5 29.3	5.84 0.76 6.60	0.96 0.73 1.69	6.30 1.49 8.29	99.5(1)	4.82(4)	2.04(4)	—	—
Id	DMA Scrubbing	23.4	5.30	0.86	6.16	99.5(1)	3.58(5)	1.52(5)	—	—
	Flash Smelting									
IIa	Single Stage Acid Plant Neutralization	8.7 5.4 14.1	1.98 0.96 2.94	0.50 0.97 1.47	2.48 1.93 4.41	97.5(1) 97.5(1)	1.45(2) 2.56	0.62(2) 1.10	— —	— —
IIb	Dual Stage Acid Plant Neutralization	9.8 5.5 15.3	2.23 1.00 3.23	0.54 0.99 1.53	2.77 1.99 4.76	99.5(1) 99.5(1)	1.61(2) 2.77	0.68(2) 1.17	0.16(3) 0.21(3)	4.15(3) 5.01(3)
IIc	DMA Scrubbing Sulfur Plant	20.2 3.5 23.7	4.57 0.76 5.33	0.73 0.73 1.46	5.30 1.49 6.79	99.5(1)	3.95(4)	1.67(4)	—	—
Id	DMA Scrubbing	18.1	4.08	0.63	4.71	99.5(1)	2.74(5)	1.16(5)	—	—

TABLE 6-12 Con't, CONTROL COSTS FOR MODEL COPPER SMELTING FACILITIES

Model No.	Control Equipment	Capital Cost ($MM)	Capital Charges ($MM/yr)	Operating Cost ($MM/yr)	Total Cost ($MM/yr)	Overall Control (%)	Control Costs		Incremental Control Costs	
							Cents/lb Copper	Cents/lb SO_2	Δ Cents/lb Copper	Δ Cents/Δ lb SO_2
	Roaster/Reverberatory Smelting									
IIIa	Single Stage Acid Plant	8.7	1.98	0.44	2.42	78.5$^{(1)}$	1.41$^{(2)}$	0.75$^{(2)}$	—	—
	Neutralization	4.8	0.87	0.78	1.65					
		13.5	2.85	1.22	4.07	78.5$^{(1)}$	2.41	1.27	—	—
IIIb	Dual Stage Acid Plant	9.7	2.21	0.48	2.69	80.0$^{(1)}$	1.57$^{(2)}$	0.82$^{(2)}$	0.82$^{(2)}$	4.84$^{(3)}$
	Neutralization	4.8	0.87	0.79	1.66					
		14.5	3.08	1.27	4.35	80.0$^{(1)}$	2.56	1.33	0.15$^{(3)}$	5.01$^{(3)}$
IIIc	DMA Scrubbing	15.6	3.54	0.77	4.31					
	Dual Stage Acid Plant	10.2	2.31	0.52	2.83	98.5$^{(1)}$	4.16$^{(2)}$	1.77$^{(2)}$	2.59$^{(5)}$	5.79$^{(5)}$
	Neutralization	5.5	1.00	0.99	1.99					
		31.3	6.85	2.28	9.13	98.5$^{(1)}$	5.30	2.26	2.74$^{(5)}$	6.22$^{(5)}$
	Reverberatory Smelting									
IVa	Single Stage Acid Plant	8.9	2.02	0.46	2.48	69.0$^{(1)}$	1.45$^{(2)}$	0.89$^{(2)}$	—	—
	Neutralization	4.4	0.80	0.68	1.48					
		13.3	2.82	1.14	3.96	69.0$^{(1)}$	2.33	1.41	—	—
IVb	Dual Stage Acid Plant	9.9	2.25	0.50	2.75	70.0$^{(1)}$	1.60$^{(2)}$	0.96$^{(2)}$	0.15$^{(3)}$	5.48$^{(3)}$
	Neutralization	4.4	0.80	0.69	1.49					
		14.3	3.05	1.19	4.24	70.0$^{(1)}$	2.46	1.49	0.16$^{(3)}$	5.69$^{(3)}$
IVc	DMA Scrubbing	17.0	3.85	0.84	4.69					
	Dual Stage Acid Plant	10.1	2.23	0.50	2.79	98.5$^{(1)}$	4.36	1.85	2.76$^{(6)}$	3.99$^{(6)}$
	Neutralization	5.4	0.96	0.98	1.94					
		32.5	7.04	2.38	9.42	98.5$^{(1)}$	5.48	2.33	3.02$^{(6)}$	4.36$^{(6)}$

Notes:

(1) Overall control efficiencies calculated assuming no fugitive emissions, no down-time of control equipment and tail gases from single stage acid plants containing 2000 ppm SO_2, from dual stage acid plants contailing 500 ppm SO_2 and from DMA scrubbing systems containing 500 ppm SO_2. EPA survey of existing copper smelters identified fugitive emissions varying between 0% and 15% of total SO_2 emissions vented to atmosphere.

(2) Acid sold at zero netback to smelter.

(3) Incremental control costs reflecting use of dual stage plant over single stage acid plant.

(4) Sulfur sold at zero netback to smelter.

(5) Liquid SO_2 sold at zero netback to smelter.

(6) Incremental control costs reflecting use of DMA scrubbing on reverberatory furnace off-gases over venting furnace off-gases directly to atmosphere.

Electric Smelting Options

Case Ia - Off-gases from the electric furnace at 6% sulfur dioxide are combined with off-gases from the copper converters at 7-10 1/2% sulfur dioxide, forming the feed to a single stage sulfuric acid plant and ranging in concentration from 6-8 1/2% sulfur dioxide. The off-gas flow rate from the electric furnace is 24,000 SCFM, while that from the converters ranges from 31,000-63,000 SCFM. Thus, the acid plant is sized to process peak off-gas flowrates of 87,000 SCFM, to produce 927 TPD of 100% sulfuric acid.

Case Ib - Essentially the same as Case Ia except this alternative incorporates a dual stage sulfuric acid plant rather than a single stage plant, resulting in the production of 944 TPD of 100% sulfuric acid.

Case Ic - Off-gases from the electric furnace are combined with off-gases from the copper converters, forming the feed to a DMA scrubbing unit. The DMA unit produces a concentrated sulfur dioxide gas (∿ 100%) which is processed by a sulfur plant. The off-gases from the sulfur plant containing 5 1/2% sulfur dioxide are recycled to the DMA unit for treatment with the combined electric furnace and converter off-gases. Due to the recycle of the sulfur plant tail gases, the DMA unit is sized to process peak off-gas flowrates of 101,000 SCFM. The sulfur plant is sized to process peak sulfur dioxide flowrates of 7700 SCFM, to produce 308 TPD of elemental sulfur.

Case Id - Off-gases from the electric furnace are combined with off-gases from the copper converters, forming the feed to a DMA unit. The DMA unit produces liquified sulfur dioxide. In this case, the DMA unit is sized to process peak off-gas flowrates of 87,000 SCFM.

Flash Smelting Options

Case IIa - Off-gases from the flash furnace at 10% sulfur dioxide are combined with off-gases from the copper converters at 7-10 1/2% sulfur dioxide, forming the feed to a single stage acid plant and ranging from 7-8% sulfur dioxide. The off-gas flowrate from the flash furnace is 28,000 SCFM, while that from the copper converters ranges from 16,000-32,500 SCFM. Thus, the acid plant is sized to process peak off-gas flowrates of 73,000 SCFM. Due to the high sulfur dioxide concentrations, air is blended with the feed to the acid plant to provide sufficient oxygen to convert sulfur dioxide to sulfur trioxide. The acid plant produces 929 TPD of 100% sulfuric acid.

Case IIb - Essentially the same as Case IIa except this alternative incorporates a dual stage acid plant rather than a single stage plant, resulting in the production of 945 TPD of 100% sulfuric acid.

Case IIc - Off-gases from the flash furnace are combined with off-gases from the copper converters, forming the feed to a DMA scrubbing unit. The DMA unit produces a concentrated sulfur dioxide gas (∿ 100%) which is processed by a sulfur plant. The off-gases from the sulfur plant containing 5 1/2% sulfur dioxide are recycled to the DMA unit for treatment with the combined flash furnace and converter off-gases. Due to the recycle of the sulfur plant tail-gases, the DMA unit is sized to process peak off-gas flowrates of 72,000 SCFM. The sulfur plant is sized to process peak sulfur dioxide flowrates of 6300 SCFM, to produce 309 TPD of elemental sulfur.

Case IId - Off-gases from the flash furnace are combined with off-gases from the copper converters, forming the feed to a DMA unit. The DMA unit produces liquified sulfur dioxide. In this case, the DMA unit is sized to process peak off-gas flowrates of 60,500 SCFM.

Roaster/Reverberatory Smelting Options

Case IIIa - Off-gases from a fluid-bed roaster at 10% sulfur dioxide are combined with off-gases from the copper converters at 7-10 1/2% sulfur dioxide, forming the feed to a single stage acid plant and ranging from 7-8% sulfur dioxide. Off-gases from the reverberatory smelting furnace at 1 1/4% are vented directly to the atmosphere. The off-gas flowrate from the roaster is 17,000 SCFM, that from the reverberatory furnace 76,000 SCFM while that from the copper converters ranges from 18,500-37,700 SCFM. Thus, the acid plant is sized to process peak off-gas flowrates of 63,000 SCFM. Due to the high sulfur dioxide concentrations air is blended with the feed to the acid plant to provide sufficient oxygen to convert sulfur dioxide to sulfur trioxide. The acid plant produces 748 TPD of 100% sulfuric acid.

Case IIIb - Essentially the same as Case IIIa except this alternative incorporates a dual stage acid plant rather than a single stage acid plant, resulting in the production of 760 TPD of 100% sulfuric acid.

Case IIIc - Off-gases from the fluid-bed roaster are combined with the off-gases from the copper converters, forming the feed to a dual stage acid plant. The off-gases from the reverberatory smelting furnace are fed to a DMA scrubbing unit. The DMA unit produces a concentrated sulfur dioxide gas (∿ 100%) which is also fed to the dual stage acid plant in addition to the roaster and converter off-gases. The DMA unit is sized to process 76,000 SCFM of off-gases and the acid plant is sized to process peak off-gas flowrates of 69,500 SCFM. The acid plant produces 946 TPD of 100% sulfuric acid.

Reverberatory Smelting Options

Case IVa - The off-gases from the reverberatory smelting furnace at 1 3/4% sulfur dioxide are vented directly to the atmosphere. The off-gases from the copper converters at 7-10 1/2% sulfur dioxide form the feed to a single stage sulfuric acid plant. The off-gas flowrate from the reverberatory furnace is 82,500 SCFM, while that from the copper converters ranges from 31,000-63,000 SCFM. Thus the acid plant is sized to process peak off-gas flowrates of 65,500 SCFM. Due to the high concentration of sulfur dioxide, air is blended with the feed to the acid plant to provide sufficient oxygen to convert sulfur dioxide to sulfur trioxide. The acid plant produces 651 TPD of 100% sulfuric acid.

Case IVb - Essentially the same as Case IVa except this alternative incorporates a dual stage acid plant rather than a single stage acid plant, resulting in the production of 660 TPD of 100% sulfuric acid.

Case IVc - The off-gases from the reverberatory smelting furnace form the feed to a DMA scrubbing unit. The DMA unit produces a concentrated sulfur dioxide gas (∿ 100%), which is combined with the off-gases from the copper converters and fed to a dual stage acid plant. The DMA unit is sized to process 82,500 SCFM, while the acid plant is sized to process peak off-gas flowrates of 75,500 SCFM. The acid plant produces 937 TPD of 100% sulfuric acid.

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